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THE

ONTARIO WATER RESOURCES

COMMISSION

REPORTS ON

CLADOPHORA INVESTIGATIONS

IN ONTARIO

1958 to 1967

REPORTS

ON CLADOPHORA INVESTIGATIONS

IN ONTARIO

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By

ONTARIO WATER RESOURCES COMMISSION

Papers Presented

at a

Conference on Problems

related to

ALGAE CLADOPHORA

in Lake Erie and Lake Ontario

sponsored by the

ONTARIO WATER RESOURCES COMMISSION

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Committee Room No. 1
(Main Building)
Parliament Buildings, Toronto

Chairman---Dr. A.E. Berry
General Manager and Chief Engineer
OWRC

I N D E X

INTRODUCTORY REMARKS

Dr. A.E. Berry, General Manager,

Ontario Water Resources Commission

This conference was called by the Ontario Water Resources Commission to review those conditions associated with the growth of algae of the Cladophora type, and the nuisances or objections resulting therefrom. An attempt will be made to cover the different aspects of this problem, to deal with causes, and to examine possible remedial measures.

Algae Problems

Complaints about algae have been numerous during the past summer. They appear to be on the increase in recent years. Their effects are felt in several ways. Some kinds adversely affect domestic water supplies by creating tastes and by choking filters. Some are toxic under certain conditions to animals drinking the water. Others grow in great profusion where the environment is suitable and later decompose in shallow waters causing offensive odors and an eyesore along the beaches. In this conference it is proposed to deal only with this latter group, the type of blue-green algae known as Cladophora.

This problem is not entirely a new one. It has been continuing on for many years, particularly along the eastern end of Lake Erie. Shoreline deposits occur each year, but the intensity of these is the variable factor. Recently the condition has worsened. Growths and shore deposits have appeared over extended areas. Complaints have been made that odors are so disagreeable that beach property cannot be utilized either for residential, recreational, or business purposes. Motels and camps are unable to attract guests in these areas. There has been confusion and exasperation on the part of the public. Different factors have been cited as responsible for this. Questions have been raised about its effect on public health. This situation, with its money ramifications, seemed to warrant the calling of this conference.

Where Problems Found

These nuisance conditions have been found in many places in Ontario, in densely inhabited areas, and in remote places. Special reference is made here to Lake Erie and Lake Ontario. In the former these growths have been prevalent from the mouth of the Grand River to the Niagara River, but most prolific in the vicinity of Crystal Beach. Periodic objections have been made here for many years, but varying a good deal from year to year. In Lake Ontario the conditions of the past summer were much worse than in previous years. Growths in nuisance proportions extended from Cobourg west to Toronto and Hamilton, and along the south shore to the Niagara

River. From Toronto to Hamilton the growth was more or less continuous.

Nature of the Deposits

The nature of these deposits along the shore has raised many questions in the minds of the public. The black color of the rotted algae and the offensive odors, described as "pig-pen", "sewage" etc. have brought forth numerous inquiries from municipal officials, beach associations, and the public in general. They have found difficulty in believing that this is anything but sewage solids, or if it is algae that it only be the result of pollution by sewage. It is to answer these questions that this conference of interested persons was arranged.

Numerous investigations have been made by the staff of the OWRC and by others. Much information has been accumulated. Studies have been made on the causes of the growth and the nutrients in the water which stimulate this growth, and experiments have been made on control measures. Reference might be made to an extended study of causes and controls in Lake Sturgeon in the Lindsay area, as well as at other points. It is apparent that a wide fund of knowledge on this exists. It is also true that there is yet much to be done, especially on all those factors which tend to promote the growth, and on control measures. These controls may involve prevention of the growth or its destruction at regular intervals. It is to be remembered that this condition becomes objectionable only after the growth has advanced to considerable volume, is broken loose from its attachment, and is washed into shallow waters, where it dies and putrifies. While it is growing in the water in its typical green color, it causes little concern, but is much like grass gowing on land.

This Conference

This conference has as its objective an examination of several factors in this algae problem. A number of speakers will present technical information, others will discuss the effects created by this condition, and an attempt will be made to examine possible remedial measures, and who, if any, are responsible for this matter. There will be an opportunity for questions and comments from all who wish to participate. The hope of the Commission is that this subject can be fully explored, accurate information supplied, and conclusions reached on what should be done in the future. The OWRC is grateful to all who have been good enough to offer to take part in this conference.

NATURE OF GROWTH

John H. Neil, Biologist

Ontario Water Resources Commission

Algae in General

As a preface to my remarks on Cladophora, I would first like to make a few very general comments on the group of aquatic plants known as algae, so that you might have a better understanding of the particular plant which we are discussing today. Later in the program Dr. Harkness will give you a much better description of algae in general, and the role which they play in the economy of water.

Firstly, all of the plants of the world are divided into three main groups and one of the three are the algae. This group is the most primitive of all the plants having no true roots, leaves, or seeds and most of the species are confined to an aquatic habitat. There are several hundred species which grow in the waters of Ontario and these range in size from a plant about four feet high down to organisms which may be just visible when magnified in a microscope 1,000 times.

As algae are plants, their requirements to live are in many ways similar to plants on land. Of prime importance to all plants is light as it is from this source that the energy necessary for the plant to grow and thrive is derived. Water is, of course, essential but aquatic algae are more fortunate than land plants as there is never a shortage of this. In addition to a source of energy and a place to live, certain foods are necessary to enable them to grow and multiply. The foods used by algae are dissolved in the water in minute quantities, so small in many cases that they are hardly detectible by the most careful and advanced analytical procedures which we have available. From the water the plant extracts many chemicals or nutrients which are essential for growth, such as calcium, carbon, nitrogen, oxygen, phosphorous, copper, iron, silica and many others too numerous to mention. It is from these building blocks using the energy of the sun that each individual cell grows, divides, and grows again. In most instances, sufficient of nutrient substances are available for an algae growth to take place wherever there is sunlight and water.

Cladophora, Its Life History and Requirements

The name Cladophora refers to several different species of this plant which grow in a variety of habitats. It appears, for instance, that in addition to the shoreline species which you are familiar with, other types grow in streams both clean and polluted and in deep water down to a depth of at least 150 feet if the water

is clear enough to permit the penetration of light.

The particular species of Cladophora which we are discussing is found along the shorelines of all the Great Lakes, abundant in some places and sparse in others. It is a branched algae which may grow to a length of about four feet. When examined under the microscope, it is seen to be composed of a single chain of very large cells connected end to end and branched from time to time. At the base of this filament of cells is a specialized cell known as a hold-fast, by which the plant anchors itself to the bottom. This hold-fast in some species at least will maintain a living cell through the winter and will produce a new filament when suitable conditions for growth return. In addition to the hold-fast method of reproduction, the plant produces spores which might be considered as seeds that are released to the water and will produce new plants if suitable conditions are found.

The species of Cladophora commonly found along the shores of the Great Lakes has a number of specific requirements which must necessarily be fulfilled before this algae will grow. Firstly, in order to fasten itself to the bottom by means of the hold-fast which I described, it must have a permanent type of bottom, such as bedrock, boulders or large gravel. It does not grow in a sand or silt type bottom. A second requirement is moving waters. On the shores of the Great Lakes there is almost always some movement in the water down to the depth to which this species grows. In the smaller lakes such as the Muskokas or Kawarthas, the water is in less constant motion and it is apparently for this reason that the Cladophora does not grow in abundance. A third requirement is the presence of plant foods in the water and it is the concentration of these nutrients that apparently controls the amount of Cladophora that will grow when the other essential requirements are fulfilled. There is also some evidence to indicate that clear water is necessary as it is not found where heavy silting occurs.

Cladophora begins to grow in the spring when the water warms up, generally in May and June slowly at first but very rapidly when the water reaches summer temperatures. It continues to grow actively until the water becomes cold, but even then may survive into the winter as fresh concentrations have been noted along the shores at that time.

The algae filaments are composed of a chain of single cells lying end to end and branching freely. Because there is only a single chain of cells, the stem is much weaker than is found in other plants as they are made up of tough fibres joined together with adhesive materials. Should one cell in the filament die or should a stress be put on the plant due to wave action or mechanical damage, this filament will break off and when water currents are suitable, these strands will be picked up and carried to the shore.

Once on the shore, the condition is a familiar one. Varying

amounts of algae will be washed up on the beach, and may extend out into the water. If the algae is washed high enough on the shore for the water to drain out, little or no odor is produced. The portion that lies in the shallow water is heated by the sun and in the high water temperature it rapidly turns black, looses its typical filamentous structure and produces the typical pig-pen odors. The odors themselves develop from the anaerobic decomposition of the plant filaments which are rich in nitrogen, and contain some sulphurous compounds. The amount of algae which comes ashore will vary depending upon the extent of the growing beds, the amount of the algae present and severity of the wind which brings it ashore. The severity of the odor problem is not necessarily dependent upon the amount that has come ashore, but more on the amount of the algae that is lying in the water and decomposing. The worst problems occur in dead water areas such as behind wharfs or in amongst large boulders and shallow water. Here the waves have not been able to roll it up onto the shore and it sits in the shallow water until it has completely decomposed or has been washed away by subsequent blows.

The amount of the algae growing in one square yard of bottom was sampled in the Oakville area last summer. The dry weight was found to be between one-third and one-half a pound per square yard. While this does not sound much, it means that one ton or more per acre may be produced on suitable bottom. Analyses performed on samples of dried Cladophora last summer, showed that it was slightly over two per cent nitrogen by weight which is about 50 per cent more than barnyard manure. One man in Oakville dug some of this material into test plots in his garden and when I saw it this summer there was no question as to which part had had the algae applied, as the plants were decidedly larger and greener than the ones in the untreated plots. Perhaps we should be cultivating this plant instead of trying to get rid of it.

The Cause of Excessive Growths

As was mentioned before, Cladophora grows in all the Great Lakes but it is only in certain places that sufficient quantities develop to cause a nuisance. Where other conditions are favorable the amount of Cladophora which will grow in a given area is likely to be limited only by the availability of nutrients until such time as as suitable growing area is completely covered. The nutrient elements in water which are most likely to limit algae growths are nitrogen and phosphorous. It is the same situation as on your lawns, where if you apply plenty of fertilizer you will develop a thick lush growth. In the same way in water, fertility will promote a lush growth of algae. The nutrients in water come from a large store which is maintained in the lake and circulated year after year together with additions from land drainage, sewage effluents, trade wastes, etc., Professor McLarty will have more to say on this subject.

Because the growth of Cladophora is continuous in suitable areas

in this end of Lake Ontario and the east end of Lake Erie, it is not possible to co-relate the growth of algae to any particular source. Apparently, the water along the shore is sufficiently rich in these areas to maintain a heavy growth. There are however, several instances in Lake Huron, and Georgian Bay where the effects of nutrients are well shown. In Lake Huron, below the towns of Port Elgin and Goderich nuisance growths of this algae occur along the shoreline for a short distance below the sewer outfalls. In other parts of the lake where no obvious source of nutrients is available, small quantities of the algae grow on suitable beds. Last summer, I visited an island in the middle of Georgian Bay that is many miles from the mainland and uninhabited. When I landed, the first thing I noticed was the heavy growths of Cladophora attached to the boulders along the shoreline. There was no apparent source of nutrients which would promote this growth but on subsequent investigation it was found that the island was extensively used for nesting by gulls and it was apparently the nutrients leached from the bird droppings on the island that had supplied the fertility for this abundant growth.

Why Cladophora Was a Problem Last Summer

It is likely that a number of factors contributed to the increased quantities of Cladophora which grew in this end of Lake Ontario last summer, and to a lesser extent the summer before. Probably, the most important single factor has been the low level in Lake Ontario. Since Cladophora is limited to a depth of perhaps 10 feet, large shoal areas which were previously unsuitable for growth because of the depth of water, are now suitable The reverse is true in certain parts of Lake Erie where in the high water years the algae was notably worse then it is at present. Here the shallow water areas where quantities of algae previously grew is dry or nearly so. This has reduced the area of suitable bottom and much less algae has developed. It seems likely that the quantities of nutrients being supplied to the lakes have increased during the past years. The use of commercial fertilizers in farming areas, the increasing urbanization along the lake and the rapid growth in the use of detergents have all probably combined to increase the supply of plant foods, in the lake in general and along the shore in particular where shoreline currents carry along the concentrated plant foods.

Conclusions

The foregoing discussion has covered a number of factors which we know or suspect will control the growth of this algae. Much of this information is based on observations we have made and on conclusions drawn from experience in dealing with other types of algae. There are, however, a number of specific questions which require answers that will require a concentrated scientific study. For instance, with regard to nutrients we do not know what the critical concentrations of plant food are beyond which nuisance quantities of this algae develops, nor do we know whether it is one or more of

these nutrients that have promoted the development of Cladophora. More information is needed on the depths to which the algae will grow, its methods of reproduction and the cause of its release from the bottom. These are some of the basic scientific problems which require further study before a permanent and satisfactory method of control can be developed.

NUTRIENT REQUIREMENTS

Prof. D.A. McLarty

Botany Dept., University of Western Ontario

The early reference of Cusanus to plant nutrition, in 1450, recognized water only as essential to plant growth. In 1804, the discovery of photosynthesis included carbon dioxide as essential to growth and later in the 19th century, chemical studies of plant materials were begun which have lead to the recognition today of about 14 mineral elements which are absolutely essential to the growth and development of all plants.

Plants may be regarded as converters. If they are supplied with the essential mineral elements they can elaborate all of the compounds which go to make up their structure. It is quite easy, in the case of commercial plants, to determine precisely what chemicals, and in what amounts, will be required for the production of a given quantity of grain, fruit or other plant produce. Nitrogen, phosphorus and potassium, used in larger amounts, are most commonly considered in practical fertilizer programs.

In a similar fashion the nutritional requirements of the Green Algae, to which Cladophora belongs, are basically well known. Given suitable physical conditions, such as light, temperature and aeration, and an adequate supply of essential chemical nutrients, normal growths of the alga may be expected in natural waters. Near my home, below a small dam on a spring-fed trout stream, a cushion of Cladophora is constantly present.

Other conditions being satisfactorily supplied, excessively rich mineral nutrient content in the water, up to a point at least, will promote excess growths of this and other algae.

Sewage effluents, both industrial and domestic, may contribute mightily to the supply of available nutrients. Staggering amounts of nitrogen, phosphorus and potassium are thus lost to society each year. At the same time run off from agricultural lands contributes measurably while in virgin territories there is a lesser but constant supply of soluble mineral substance to natural waters from the soil and bed rock surfaces concerned.

With respect to sewage effluents, treatment is not a matter of concern in this connection. In all commonly used processes the minerals ultimately reach natural waters at the outfall from the system. The form in which they arrive and the time at which they will be available for the support of algal growth will vary but the ultimate result is the same. Mineral nutrient elements are not

commonly removed. In fact, the more complete the sewage treatment the more immediately available are mineral components for the support of algal growth.

When control of excessive algal growth is considered attention is given immediately to sewage disposal systems not because they are the only factor in excessive mineralization of natural waters but because they are the only sources of mineral which lend themselves to any effective control whatever. Some control may be exercised by reducing or eliminating the chemical elements normally discharged from sewage disposal plants. This can be done if the demand is great enough and indeed it is already being done in some municipalities.

On a local basis, chemical control of excessive algal growth may produce some results and some new problems.

Thinking purely in terms of attempting control by regulating nutritional factors, the process might be difficult. It would probably be a gradual process in view of accumulations of nutrient materials having to be slowly exhausted. Finally the reduction in dissolved mineral elements and of the associated algal production could, by this means, be reduced only to the level which might be regarded as normal for the location.

EXTENT OF POLLUTION IN THE AFFECTED AREA

G. M. Galimbert

Director, Sanitary Engineering,
Ontario Water Resources Commission.

The problem created by the presence of algae in water is becoming a matter of major concern to municipalities on the shores of many lakes and rivers in Ontario. Several varieties have created considerable difficulty in the treatment of water but fortunately equipment is now available that can effectively eliminate such algae as it enters plants. Today, we are discussing another variety of algae, Cladophora, that has caused and may continue to cause objectionable conditions along the shores of many lakes, and in particular, Erie and Ontario. The problem created by Cladophora is not easy to solve and the main hope is in the extensive research programs that are being carried out in Canada and the United States on the elimination of nutrients that are suitable for food for this algae from sewage effluents and in the development of more effective algicides to be used at times of the year that will give the best results.

Improvement of Sewage Treatment Plants is Not Entire Correction

You will note that the improvement of sewage treatment plants is not held out as the cure-all for the elimination of this algae. In fact, it must be categorically stated that if every sewage plant is improved so that it provides full secondary treatment, there is every possibility that the growth of this algae may even be more prolific.

Increase in Nutrients Suitable for Plant Life in Sewage

There has been a definite increase in the quantity of suitable plant food nutrients available in sewage due to the wide-spread increase in sales of a variety of synthetic detergents. Such nutrients are only partially eliminated by the existing types of secondary treatment plants and some proportion leaves the plant in its original or in a partially degraded form through the effluent. From research, there is some indication that control of operations in a fully designed sewage plant can effect a greater removal but there has been no overall corrective method developed as yet. It is interesting to note that in the same period that has seen the increase in nutrients suitable for plant life arriving and passing through sewage plants, that algae of many types including Cladophora, have appeared in the lakes in quantities that have caused concern in the operation of water treatment plants and to shoreline municipalities due to offensive deposits of rotting algae.

Algae or Sewage?

There have been differences of opinion as to whether deposits along shores are algae or are sewage. In fact, like the old riddle of "which came first, the chicken or the egg" there has now been added another, "which came first, the algae or the sewage." No doubt, offensive odors that emanate from rotting algae along a shoreline can readily prove convincing to the inexperienced that it is sewage. Yet, this algae is found at many places along lakes or rivers where no sewage discharges are in close proximity. It is also true that gross discharges of relatively raw sewage can be made without algae development in quantity, whereas prolific growths can be present in areas close to discharges from excellent sewage disposal plants turning out good effluents. A comparison is readily afforded by the sewage plants of the City of Hamilton and the Township of Trafalgar. In the first instance, the discharge of about fifty million gallons of raw sewage with only a minimum of treatment is made daily to Hamilton Bay and there are reports of gross bacterial pollution but no prolific algae development. Trafalgar Township, on the other hand, has an excellent plant discharging a good effluent and there is little bacterial pollution near their outfall but still there has been development of prolific growths of algae. Certain conditions for the development of this algae are therefore necessary beyond the presence of sewage.

Ideal Location for Development of Cladophora

The ideal location for the development of offensive conditions caused by Cladophora is a shallow, rocky shoreline, open to wave action and in relatively close proximity to a sewage effluent that will provide the nutrients suitable for plant growth. The fact that the sewage plant is operating efficiently may readily increase the adverse algae conditions. There are many such ideal locations for the growth of Cladophora on Lakes Erie and Ontario but it is doubtful that any is better than the one that exists just east of Crystal Beach on Lake Erie. Conditions have been unsatisfactory in that area for many years and many attempts have been made to eliminate the algae by the use of algicides and by improvement of the sewage treatment but without success. Other trouble spots of major importance exist along the shoreline of Lake Ontario between the Humber River and the Etobicoke Creek and in the Clarkson-Oakville-Trafalgar area but sporadic deposits can be found almost everywhere along the shore.

Major Improvement Taking Place in Sewage Treatment

Major programs are in progress or under consideration for improved sewage disposal facilities by municipalities along the shores of Lake Erie, the Niagara River and Lake Ontario. In the forefront is Metro Toronto with its present program of conversion from primary to secondary treatment for an estimated discharge of 135 million gallons a day. Such a program will take several years to complete but will

eventually mean a vastly improved water in the lake from a bacterial standpoint all the way through Metro Toronto including the area in which algae growths are not so prolific between the Humber River and the Etobicoke Creek. Increased residential and industrial demands in several municipalities now require either the extension of the present installations or the provision of new treatment plants. Municipalities in that classification include Grimsby, Beamsville, Burlington, Oakville, Whitby, Cobourg and Bowmanville. In each instance either an extension or treatment in a second plant is planned. New sewage treatment plants or major extensions to the existing facilities are required at Port Dover, Crystal Beach, Niagara Falls, Niagara, Hamilton, Toronto Township, Trenton and Belleville. These municipalities have either no sewage treatment whatsoever or installations that are definitely inadequate at the present time. Toronto Township is placed on this list but it must be indicated that in the very near future it will be installing a modern plant to replace its temporary set-up to take the sewage, not only from Toronto Township but also the overload from the Long Branch plant of Metro. In all the other municipalities indicated, definite studies are being made at the present time and plans are being prepared for the installation of treatment.

Vast Improvement in Sewage Treatment Can Be Expected

It can be stated that there is every evidence that a vast improvement in sewage treatment can be expected along the shores of Lakes Erie and Ontario. The question immediately arises, "What effect will this have on the algae conditions?" My candid answer is that it will have little, as far as the algae growths in the lake are concerned. The effects of sewage discharge to the lake, even though properly treated, will still be felt. Depending on the wind current, effluents will travel and reach a wide area. An on-shore breeze will still bring the treated sewage with its food nutrients to the fields in which the Cladophora is prolific. If better methods are not found to eliminate nutrients suitable for plant food from sewage or more effective algicides are not developed, there still will be prolific growths of algae. They will continue to break off with wave action and deposit and rot on the shore. The only other alternative would be a tremendous cut-back in the sale of products that introduce nutrients to sewage which modern treatment does not eliminate or degrade. One of the main hopes for the solution of this particular problem, the elimination of algae, is not the provision of secondary treatment at sewage plants but that research will find a solution to a more effective elimination of food nutrients suitable for plant life and the development of a more effective aglicides. The provision of secondary treatment plants does remain a prime requisite in the overall clean-up of the lake waters even though it is not the solution as far as this algae condition is concerned.

EFFECTS OF DETERGENTS ON NUTRIENT SUPPLIES

A. V. DeLaporte

Director, Laboratories & Research,
Ontario Water Resources Commission

Vegetation, both macro and micro, has very definite nutritional requirements. The three basic needs are nitrogen, potassium and phosphorus.

Doctor Clair N. Sawyer stated at a meeting of the New England Water Works Association (November, 1951)

"The biological problems most prevalent in lakes are a result of prolific weed growths in littoral areas or of algal blooming. In the first case the nuisance is due largely to interference with recreational activities, such as, boating and bathing; in the second case, it is a result of obnoxious tastes and odors carried in the water or generation of aerial odors of such intensity and repugnant character as to materially influence shoreline land usage.

"Lakes vary greatly in their productivity of algal blooms and areas of rooted vegetation. Of late years, much evidence has accumulated to confirm the beliefe that inorganic and organic fertilizers containing nitrogen and phosphorus are the major factors influencing the extent of such growths.

"Liebig's Law of the Minimum, shows that the variation in productivity of land areas is most often determined by limitations imposed by a lack of some nutritional element. It is reasonable to assume that micro and macro aquatic plants respond to the same factor."

From all the evidence, it appears that phosphorus is the stimulant for their growth. The increased phosphorus content of the waters of some of our rivers and lakes is believed to have a direct relationship to the increase in the frequency and intensity of algal blooms. A few decades ago the determination of phosphorus in sewage or sewage effluents was seldom done as a routine. The phosphorus did not enter into the treatment processes, nor was it removed by them. Incidentally, the methods of analyses left something to be desired in accuracy when dealing with a two part per million or less, (Sawyer gives 2 to 4 ppm). The entire picture has changed today. The phosphorus content of sanitary sewage has increased in some instances to 100 parts per million or more. This increase in phosphorus in our wastes is attributed to the increase in the use of synthetic detergents, most of which contain phosphates.

Assistant Surgeon General, Mark Hollis, of the United States Public Health Service, states in a recent publication that, "use of detergents has grown by 2 billion pounds in the last seven years". In the United Kingdom the consumption of surface active material (detergents) increased from 28,600,000 in 1949 to 90,200,000 pounds

in 1956. The best figure I can get for Canada is 138,156,180 pounds used in 1955. This tremendous expansion in the use of surface active material has created many knotty probelms, foaming in water supply, in sewage treatment, pollution of wells by detergents via septic tanks. Solutions for these problems are not simple and can prove costly.

Numerous investigations into means of removing phosphorus from sewage have been reported. Willem Rudolfs reported (Sewage Works Journal, January, 1947), the removal of phosphate by coagulation with lime to be quite effective. The data from studies of the Sedgwick Memorial laboratories, indicate that the total soluble phosphate content can be reduced to about 0.5 ppm by lime treatment. The studies showed that ferric chloride and alum are also highly effective in removing all forms of phosphate. Sawyer, in a paper (Sewage Works Journal, September, 1944) demonstrated that phosphorus can be removed by sewage by the Activated Sludge process, provided the B.O.D., phosphorus, ratio is properly adjusted, but concludes that the method is not practical as it involved feeding carbonacious matter to maintain the B.O.D. phosphorus balance.

An attempt to prevent the algal blooms by removal of the phosphorus from the effluent of the Lindsay sewage treatment plant, indicated that under the geographical conditions prevailing there, that the blooms could be controlled by removal of a large portion of the phosphorus being discharged into the lake. Alum and activated silicon were the chemicals used to precipitate the phosphorus in the sewage treatment plant. About 90 percent of the phosphorus in the raw sewage was precipitated. The experiment was too short to be entirely conclusive. It seemed apparent that lowering the phosphate input into a body of water would lower the frequency of algal blooms, and would lessen their severity.

The answers to the problem of foaming seems to be the elimination of the foaming compound in the detergents. The manufacturers are loathe to do this, not because the foaming agent helps the cleansing action, but because the housewives accustomed to soap seem to like the foam.

In case it would seem that detergents are the only source of phosphorus in the sewers, I would call attention to the use of a number of new synthetic organics which contain phosphorus. Parathion and Malathion are pesticides in common agricultural and garden use. Malathion is probably the most efficient fly killer in common use. The increased use of super phosphates by farmers has been significant. An extreme example of how an agricultural use can pollute a stream occurred in Georgia. An area of land, planted in cotton was sprayed to control the cotton ball weevil. The spray used was toxic. This destroyed all the animal life in the stream for several miles. This section of the stream, according to reports, remained barren for several years, due to the residual toxicity in the bottom deposits.

Before the last war, an area in Lake Erie (infested with Cladophora) was sprayed with a copper sulfate solution. The algae were killed, wave action piled the dead algae on the shore with a result that is familiar to many residents along the north shore of Lake Ontario. The water area did not remain free from Cladophora. In a comparatively short time the growth was a profuse as ever. A study using synthetic organic algicides has been undertaken. At Sturgeon Lake, a non-toxic organic fungicide was used with some success. Further studies are contemplated. It would seem, however, that adequate control would require several applications of the algicides a year.

Summary:

(1) It is evident that in accordance with Liebig's Law of the Minimum, removal of phosphates from a water appears to be a successful method of limiting algal growth.

(2) Control by algicides is possible, but the cost might be prohibitive.

PUBLIC HEALTH ASPECTS

Dr. C. C. Stewart, M.O.H.

Oshawa, Ontario

With the steady increase in the amount of Algae Cladophora appearing along the Oshawa waterfront in recent months and years, there have been an increasing number of complaints reaching the City Council, the City Engineering Department, and the City Health Department from the citizens residing along the lakefront. The people invariably complain of the intensely unpleasant odor of the decomposing algae.

The staff of the Local Board of Health can only explain to the complainants that neither the algae nor the odor constitute a danger to health and that the problem, therefore, is not one that falls within the scope of the City Health Department.

The Engineer in charge of the City Water Purification Plant informs me that at certain periods the algae tends to block the screens, and in the settling basins imparts some taste and odor to the water. These situations are corrected by periodic cleansing of the screens, and by treating the water with activated carbon which is removed in the process of normal filtration. Although it necessitates two extra simple procedures at the plant, the algae does not affect the quality of the city water supply. Further, since it is a marine growth that does not develop dangerous micro-organisms, the algae cannot be considered, from the medical point of view, as affecting the safety of the untreated lake water.

In short, then, although in its decomposing state Algae Cladophora produces an almost intolerable and most undesirable odor, it does not constitute a danger to health, and therefore as a problem falls outside the scope of the Local Board of Health.

THE PLACE OF ALGAE IN NATURE

Dr. W.J.K. Harkness

Chief, Division of Fish & Wildlife
Dept. Lands and Forests

Algae is present in abundance in all natural waters. It consists for the most part of countless millions of microscopic plants floating about freely in the water. Some species grow in the form of groups or colonies which can be seen quite readily with the naked eye. There are a few filamentous species which form the so-called pond scum or frog spittle, and even some larger forms of algae such as the Cladophora are attached and have superficial resemblance to land plants.

These algae, then, constitute the plants of the water corresponding to the meadows and forests of the land. Like the leaves of land plants they contain the green-colored chlorophyll and can live only in the sunlight, so that 90 per cent of them are found in the upper 30 feet of water. In sunlight they use up the carbon dioxide and release oxygen, thus purifying water by this photosynthetic action.

Algae is absolutely essential to life in the water. It is the pasturage of the water just as the meadows and forests are the pasturage for land living herbivores and browsers. In so far as it forms the basic food, many fish feed on it directly while other fish are dependent upon the hosts of aquatic animals, both large and small, which in turn are dependent upon it for food. Its oxygen-producing activities make it possible for fish to live in our waters.

Algae varies in abundance, with blooms occurring in our lakes in the spring and fall. These blooms occur in the spring and fall, as these are the seasons when the waters of our lakes are at the same temperature from top to bottom and when, as the result of spring and fall gales, they undergo the turn-over which brings bottom waters to the surface.

These bottom waters which have been far below the area of algae growth have accumulated a high concentration of nutritive substances. When these fertilizing substances come to the surface, there is a great stimulation of algae growth resulting in the seasonal blooms.

This is a typical example, of which there are many, demonstrating the natural stimulating effects of nutritional substances or fertilizers on algae growth.

River waters flowing into a lake are rich in nutrients which they have dissolved from the soils of the drainage basin. When these waters flow into shallow bays such as the Bay of Quinte, Long Point,

and Humber Bay, there is a notable stimulation of algae growth. This, in turn, results in a very marked increase in fish production dependent and attributable to the algae growth.

There are many examples where special sources of nutrients or fertilizers stimulate algae growth.

Among organic substances we have the condition produced by the natural death of fish, as for example the salmon of British Columbia streams which die after spawning, or the man-made condition of sewage effluents or drainage from fields after application of barnyard manure.

Among chemical substances we have the phosphates resulting from the use of detergents or again the run-off from fields treated with chemical fertilizers.

The natural or artificial conditions stimulating algae growth may cause blooms which create serious nuisances, and such nuisances may be caused by clean water algae such as Cladophora growing under conditions which are not harmful or detrimental to the normal life of the water but only to some particular phase of human interest or activity.

Among the open water free floating types of algae there may be such an increase in numbers that they plug water intake filters and create other water treatment problems. Certain forms of toxic, malodorous or taste-producing algae which are innocuous in normal numbers may be stimulated to such excessive numbers under certain conditions that they create a nuisance.

It is easy to see that just as we have weeds such as daisies and sow-thistles in the farmers' meadows or undesirable weed trees in the forests, we can have similar weed conditions with algae, brought about by the excessive production of undesirable species in troublesome numbers which produce real problems for water users - whether the water is being used for domestic purposes or in its natural condition along shores for aesthetic purposes of recreation such as bathing, swimming and angling.

In dealing with the algae problem we are confronted with a natural situation which has been modified by human intervention very similar indeed to the conditions with which the farmers or other land-use managers are confronted.

THE USE OF ALGICIDES

John H. Neil, Biologist

Ontario Water Resources Commission

What are Algicides

Algicides are chemicals which are put in water specifically to kill algae just as insecticides are used to kill insects. Because of the limited potential market for these chemicals the larger pesticide manufacturers have not devoted much research to their development. Consequently the algicides which are available are those which have been used for many years or are chemicals which have been developed for other uses and were accidentally found to have an algicidal action.

Considerations in the Use of Chemicals

In order for an algicide to be suitable for use in a surface water there are several factors which must be considered. Firstly, it must be safe to use from the standpoint of human and animal consumption and must be non toxic to fish and other aquatic animals at the concentrations applied. Secondly, it must not interfere with other water uses such as drinking water for municipal use or irrigation of crops. Thirdly, it must not be too expensive for general use.

With respect to the consideration of safety, one of the most effective chemicals is sodium arsenite. When applied carefully and in the correct amounts it will work very well but it is an arsenical and constitutes a hazard to the sprayer and there is always the possibility of concentrated pockets that could cause poisoning to humans or animals and for this reason is not recommended. Several other complex chemicals have been shown to be effective in killing algae of a similar type but they are toxic to fish and other aquatic life in the concentrations necessary to kill the algae and for this reason are unsuitable.

There have been a number of herbicides for land use come on the market recently which will also work in water. These, however, have a phenolic base. When waters containing phenol are chlorinated for municipal use Chlorophenols are developed which produces an objectionable tase in extremely small dilutions (five parts per billion) much below the concentration necessary to kill algae. Thus phenolic base chemicals can not be used.

Certain other algicides that are used for treating swimming pools are effective but the cost of using them is prohibitive.

Discussion

The foregoing considerations leave only a few substances that appear promising. So far as is known now copper sulphate or blue stone offers some hope but more work is required to determine the

correct concentrations, the best method of application, the best times of application and the length of time before regeneration. Similar information will have to be obtained for other promising algicides.

Very recently a new substance was reported in biological literature as being effective in controlling Cladophora but information has not yet been obtained on chemical composition, price, etc. If it appears suitable it will be field tested.

There are a number of possibilities whereby the cost of application might be reduced that require further investigation. For instance, this algae grows attached to the bottom so that if the chemical could be applied in such a way that the material is concentrated in the bottom foot or so of water it would save the cost of treating the whole volume of water over the beds. There is also the possibility of combining the chemicals in such a way that it dissolves slowly thereby exerting a control for a longer period of time. This may be important if it is found that the algae after kill regrows quickly.

As may be seen, there are a number of problems connected with the use of algicides. Further information is needed to determine whether chemical control using algicides which do not interfere with other uses of water is economically possible.

When consideration is given to the control of Cladophora by a chemical means it is necessary to bear in mind the scope of the problem. Here we are considering an irregular band of vegetation extending various distances into the lake more or less continuously for 30 miles between Hamilton and Toronto and for another 10 or 15 miles along the north shore at the eastern end of Lake Erie. The cost of treating such large areas even with a suitable algicide will be quite expensive and for this reason the possibility of natural control by the limiting of nutrients or other factors influencing growth should be investigated.

THE MUNICIPALITIES' VIEWPOINT

Mrs. Marie Curtis

Reeve, Village of Long Branch

Mr. Chairman, ladies and gentlemen:

I have listened with a great deal of respect to the expert people today on this panel. They have told us about all the causes and all the effects of algae, but I sense, as I look out into this group of citizens assembled here today from all areas of Lake Ontario and Lake Erie, a look of despair. It is all very well when one lives removed from it, but when you live right on it or a block or two close to it, it is a pretty grim situation.

I would like to say that I guess pollution of the Lake 20 years ago started me on my wild career because it was pollution of the Lake out at Long Branch that really got me interested in municipal life. At that time we were completely by ourselves, a little village which simply did not have the money at that time to increase the facilities of our disposal plant. This was widely known, but through a lot of pressure, might I say, the capacity of the disposal plant at Long Branch was increased. Then the need for even greater capacity became apparent again. I think one of the reasons we have a metropolitan form of government is to take care of those areas such as ours, where the essential services were being neglected because of lack of funds. We who were in the arena knew full well that Long Branch did not have the capital requirements to go ahead and build a larger disposal plant together with all the other essential services that were needed in the community.

I would say that Long Branch's disposal plant is not as overcrowded as it was due to the fact that Etobicoke's sewage which was coming down in several mains to our plant, is now being treated by one of their own but nevertheless, Long Branch is pretty well at capacity right now and the need is there for a new one.

Now, Metropolitan Toronto, which has been reported here to have made great advances in the way of a new disposal plant, has not gone far enough yet. I don't need to tell the audience, nor the learned gentlemen here, of the great need for further disposal plants. But when I take it up with Metro, and ask why don't they spend the money for disposal plants, one of the things that Metro is set up for, they say they are making great progress, and they are, but they claim they can clean up all Metro waters, but what about the rest of Ontario that is polluted. I think you heard of another large city here today that is dumping raw sewage right into the bay, yet strangely enough they are not receiving this terrible condition on their shores that the people of the lakeshore and parts of Lake Erie and down around Oshawa are. It is hard to explain to your people--we who are the whipping boys they can get at--that the algae problem isn't caused directly by one municipality's sewage plant, and that all the disposal isn't going from one place directly into their back yard, because

they cannot conceive that it has come across a lake or anything else. Now, I have not said that the Long Branch plant didn't put anything out into the lake, because I know it has been doing that for the 20 years as I have just related to you.

I maintain that, as well as the engineering report here about the need for research, one of the reasons the Ontario Water Resources Commission was set up was to make it an independent body to do just these things, I know they have it in the Act, that irrespective of any other Act, it has the power to see that we have proper disposal plants in Ontario, and while it is a new body--I know you can't change the world or a situation in a year--I feel that out of this conference we, who represent municipalities, would like to go back home feeling that here in this area while sewage is not directly responsible for algae conditions, it is helping indirectly to grow it like the fertilizers we hear about. It is coming up on our beach land and it is hard to tell the citizens who have it at their back door that this is not injurious to health, because families in my community have told me that they have not even been able to eat at home at times because of the odor. The children would become sick. While you couldn't say that it was directly bad for health, nevertheless, indirectly it is a terrible condition on our shores.

I am very pleased with the Ontario Water Resources Commission for calling this group together, and I am very pleased with those who took time out to come down here today to show the Ontario Water Resources Commission and their experts that this is a serious problem facing you people. I know they are no different than anyone else in office--they have to know the feeling of the people. I often say I have to have you at my back in order to do things and I think they have to have us at their back to do this.

Metropolitan Toronto, where I come from, is going ahead on these things, but not fast enough to my way of thinking. They are spending money on other things which I won't mention today, but nevertheless I take it that this group has decided the whole of Lake Ontario should be cleaned up and the Government has given them the power. I sincerely feel that cleaning up the lake will do something, along with the research, which, as the engineer pointed out to us here, is being made. Maybe we ought to, the municipalities in particular, give some more money to this research, so they can, aside from the pollution angle of the disposal plants, do some research to overcome this algae condition so that our lake shores will be free again. I had people, Dr. Berry, who couldn't even get their boats out this summer. It was really getting serious, but now its gone. Some people have forgotten the smell already, but next summer is coming and the people are desirous of action to prevent its return. I thank you for inviting me, and I hope and sincerely pray that we arrive at a solution and that the lakes are cleared of pollution and other matters.

Mr. J.C. Saddington

Deputy Reeve, Port Credit, and chairman of an association of Lakeshore municipalities, interested in the problem.

(NOTE: In the interval between the meeting and publication of this report, Mr. Saddington was elected Reeve of Port Credit, by acclamation.)

Mr. Chairman, ladies and gentlemen, I think my first words should be words of thanks to the Ontario Water Resources Commission for inviting us here today, to hear of our problems with algae. We in the municipalities can't fight this problem alone. We haven't the funds for research, we haven't got the organization and yet the problem is right on our doorstep. We, in Port Credit this summer, found ourselves particularly helpless when we had ratepayers question us about algae and pollution, because I don't think of algae alone, I think of pollution, oil, sewage and all the rest of the corruption that is in the lake.

We in Port Credit this year felt that this wasn't a problem of this year, it wasn't a problem of next year, but as this area along the lake develops this question of clear waters is going to become more and more aggravated and it is a problem which will require continual attention and work. As a result of that, Port Credit invited 24 municipalities along Lake Ontario, from Cobourg to Hamilton, to visit us in Port Credit, with a view to forming an association this fall. We had 12 municipalities represented and an organization was formed.

The reason for that organization, I believe, is probably threefold. One is that as a body dealing with the Ontario Water Resources Commission we can keep it informed of the pulse of the people; secondly we can be kept informed as a body, more easily than as individual municipalities. Our experience has been that acting by ourselves we probably write a letter about it to the higher level of government and we get a reply, but that is not enough. The ratepayer is not interested in that and he feels that we should go further. The third purpose of the association is to develop, in such a way that we can co-operate with the Ontario Water Resources Commission and any other government departments, with a view to assisting them in bringing about whatever is required to fight this question of pollution.

We, as municipalities, realize that probably the first places we have to attack are our own doorsteps. I think we are prepared to do that. We may not be able to correct the situation immediately we see the trouble there, but at least we can recognize in the midst of ourselves that we have troubles. We are also closer to industries within our municipalities, much closer than the higher levels and with direction from the Ontario Water Resources Commission and co-

operation between the two bodies, we feel we can help them accomplish some progress towards abating this problem. That is about all I have to say.

This organization I speak of is in the baby stage and we have had only one organizational meeting yet, but you are to hear more about it in the very near future and as presently constituted, we welcome any municipality that borders on Lake Ontario to join us. I might just close by--this has got nothing to do with pollution, but it has to do with the taste of water--telling you about what I think is a little humourous incident that happened this week. We had a council meeting on Monday night and the Reeve happened to mention that one of the ratepayer whiskey drinkers phoned him and said that he couldn't drink his whiskey because of the taste of the water. I don't know what radio station it went over, but I am told it went over one of them, and yesterday morning the Reeve got a telegram from St. Louis, Mo., from Passo's and it said--send your whiskey drinkers down to us, we have good water and we need the business.

QUESTION-AND-ANSWER SUMMARY

Some of the answers brought out during the question-and-answer period which followed presentation of papers:

Algae Cladophora is not toxic--it is not a public health menace--but it is most unattractive and emits an odor when decomposing--a non-toxic odor.

The term "pollution" should not be confused with algae growth itself.

Despite the fact that sewage, both raw and treated, reaches Lake Ontario, water supplies taken from the lake are of high quality because of dilution, effective operation of filtration plants and the use of chlorine.

Growth of algae in the Great Lakes is not confined to Canadian shores only--it is an international problem.

Among factors in successful growth of algae are aeration created by agitation of the water and certain types of rock formation.

So far, the best way to get rid of algae is to rake it up.

As far as is known there is no relationship between the facts that at Port Dalhousie in summers when there is no algae, dead fish are washed up on to the shore. Similarly, when there are no dead fish there is algae growth.

Small algae-bred flies, which have caused some distress in some lake shore communities, are harmless as long as they confine their activities to algae itself which, under normal circumstances, does not contain disease carrying properties.

Oil found with some algae deposits has nothing to do with oil pollution, but comes from food made by algae for itself. This food often takes the form of starches and oils.

Value of removal of phosphorus from sewage in treatment plants is debateable because it is not definite that phosphorus is an algae nutrient--such removal procedure constitutes an expensive procedure which possibly has little or no value.

More research is needed, and money is needed to further that research.

It was suggested that, since Algae Cladophora does not attach itself to sand, money be spent on shore retention projects such as re-sanding of disappearing lakefront beaches.

IN SUMMATION

Dr. A. E. Berry

In the first place I am sure you will all agree that this has been an excellent conference which brought out much information on this important subject. Maybe the solutions are not so obvious as some would like and that is, as Dr. McLarty has said, due to the fact that it is a very complex problem. The various papers have been most enlightening, and we are greatly indebted to those who participated. They have shown clearly the conditions under which this algae will grow. Nutrition is obviously one of the major factors, but there are many others. There are the conditions along the shore which make it possible for algae to attach itself to the rocks and then to drift in to bays where it can lodge and decompose. All those are necessary in order to get this prolific growth. As far as sewage pollution is concerned I think it has been clearly shown that sewage may be a factor of growth, whether it be raw or treated, but the disconcerting picture about this is that the higher the degree of treatment of the sewage the greater the availability of nutrients for the algae to feed on and be stimulated. But then there are so many other factors involved in providing nutrients for these, whether it be drainage from the land, from creeks and various other places, that it is difficult to assess in any particular place whether the sewage is the major factor or whether it is this other drainage. That is certainly one point that needs consideration.

Mr. Galimbert started with referring to research, and I think you all agree that any studies or research on a problem so complex as this is highly desirable, and it is not one of those things that can be undertaken with the idea it is going to be solved next week. This matter has been under study for many years, and we are hopeful that there will be a development of algicides that will be much more effective than they are at present. One of the difficulties I see as far as algicides are concerned, is that if you could confine water so that it doesn't move about, you could put a chemical in the water that would kill this material quite readily, but as soon as you put copper sulphate or these others in, the waves come along and dilute it before it has time to kill the algae. This is one major problem of the many associated with algae control.

Detergents have been considered this afternoon, and, as Mr. DeLaporte has said, the increased use of detergents has shown or has corresponded with an increase in algae. Whether that is a significant item, I don't think anyone can say, but it is noted that there has been a good deal of relationship, of timing at any rate, between algae and detergents.

We are pretty well agreed that as far as the algae itself is concerned it is not a public health problem. It is a very disagreeable nuisance, not a public health nuisance, but a very disagreeable condition to those people who have to live on the shores near where it grows. Whether or not it is a public health feature is not altogether

the important point. I think with public health today we are concerned with good living conditions and good environment. Where there are odors that satisfactory environment does not exist.

Dr. Harkness, in his paper, referred to the fact that these algae are the pasturage in the water the same as pasturage on soil, and I think that is quite an important matter. The problem is not so much that algae is present under certain conditions, but is this excess stimulation of the growth.

Then we have heard very effectively from representatives of the different municipalities, Reeve Curtis, Mr. Saddington, and others. They revealed the problems that are faced in these different places. Finally, what is the answer to this? Is it something that somebody should be doing right away, and how are we going to do it? The suggestion that this material be raked up on the shore as soon as it comes in, we know, is difficult in some places. At the same time, we do know that if raking is carried out it does overcome the nuisance problem. But there are many places that can't be raked readily, while immediately arises the problem of who does the work. Should the municipality spend money on private beaches or should it be done by the individuals? As far as Crystal Beach is concerned, we have advocated for years that raking was the answer to that problem, and we know that where people did rake it out, it was satisfactory.

As far as research studies are concerned we are very keenly interested in them. I am sure the biologists of our Commission and other Departments, and Dr. McLarty, the University of Western Ontario biologist, are all interested in going on with this. I hope that we can develop further some of our research programs on this. It is remembered that a good deal has been already done. Reference has been made to the studies carried out on Sturgeon Lake in an attempt there to see what could be done. Mr. DeLaporte has just made the suggestion that as far as the Trafalgar sewage treatment plant is involved, it might be a good place to experiment with a type of treatment, by chemical precipitation, to remove the phosphorus, because it is a site that would lend itself to this. Thus there would be an opportunity to see whether the removal of the phosphates from the water actually had any effect. It would answer the question, I think, of whether the environment there, apart from the sewage, is satisfactory anyway for this intense growth.

I would like to make some reference to what the Water Resources Commission is doing in respect to sewage treatment, and Mr. Galimbert, I thought, brought that out quite well in his statement that a great deal is being accomplished today. We made reference to places where difficulties have been experienced, Hamilton being one, but Hamilton as I said before is embarking on a very ambitious program for cleaning up. But that certainly is not going to change the situation, at least we don't expect it is going to change the situation as far as the lake is concerned, and these other municipalities are all going along on sewage treatment programs. There are problems still to be encountered, and it is the question of finances in so many of these places. I am sure that if your organization, Mr. Saddington, and other

groups will co-operate with the Water Resources Commission, as you have indicated, it will help a good deal to get this work under way quickly. We will find means of financing it, I am sure, some way, before too long. We will welcome the opportunity to work with the various groups both before this condition occurs next year and when and if it does occur. If the water level is different, if weather conditions are different, we may have something entirely apart from what took place this year. Let us hope anyway, it won't get worse, it will get better.

Hugh Lumsden, Land Surveyor,
Burlington.

I would just like to say, that as one who has lived on the shore of Lake Ontario for the past 15 years, I have been very interested in this growth of algae. Up until today I knew little or nothing about it, but I have certainly smelled it and have seen much of it. As a result of today's very excellent talks which we have had, I think we, one and all, have learned an immense lot about this problem and I think, furthermore, that we are very much reassured to f. l that the Water Resources Commission has the matter very much to the fore and is doing all possible in the way of research to improve the situation. I feel sure, therefore, I am echoing the feelings of all present when I say that we owe very sincere thanks to Dr. Berry and all those who have taken part in the program for a very interesting and instructive afternoon.

CLADOPHORA INVESTIGATIONS

- 1959 -

A Report Of

OBSERVATION ON THE NATURE AND CONTROL OF EXCESSIVE GROWTH OF CLADOPHORA SP. IN LAKE ONTARIO

By

THE
ONTARIO WATER RESOURCES
COMMISSION

CLADOPHORA INVESTIGATIONS

- 1959 -

This publication contains a record of research work carried out by the Ontario Water Resources Commission in the summer of 1959 on the nature and control of algae Cladophora growth. For many years this type of algae has caused widespread nuisances in the lakes and streams of the Province. It grows in great profusion under favorable conditions, and when wave action detaches it from the rocks it washes into shallow areas where decomposition sets in with resultant offensive odors.

This growth has been prevalent in many parts of Ontario, and is stimulated by a good environment which includes sunshine and presence of food in the form of fertilizer. Control of the environment is usually too difficult, thus making other measures necessary.

The studies noted in this report resulted from attempts to destroy algae in its early growth through chemical treatment of the water. A number of methods were carried out, and encouraging results were obtained. However, the investigation is not yet completed, and more field work will be carried on before a full assessment can be made of the various measures.

It is gratifying to report that the results to date give promise of an effective attack against a long-standing nuisance problem.

A M Snider
Chairman

A. E. Berry
General Manager

ACKNOWLEDGEMENTS

The co-operation of the Geophysical Group of the Research Division of the Department of Lands and Forests is gratefully acknowledged. The exchange of information, personnel and equipment was most helpful. Most particularly, the services of Mr. David Whiteman and Mr. W.R. Franklin, captain of the tug "Plainsville", were appreciated.

Dr. Roger Dean and his assistants aided us materially by conducting diving operations to determine conditions prevailing on the lake bottom in the areas studied.

Technical officers of a number of chemical companies provided very appreciable aid through generous donations of time and materials. Special mention should be made of the Shell Oil Company of Canada, The Shell Chemical Corporation, Chipman Chemicals Limited and Rohm and Haas Company.

TABLE OF CONTENTS

SUMMARY and RECOMMENDATIONS

Summary

1. Cladophora is found growing along the northwesterly shores of Lake Ontario wherever a suitable rock bottom is found and in waters up to and slightly exceeding six feet in depth. In water approximately 10 feet in depth growth of the alga is negligible. In these areas, lack of water movement and limited aeration may be important in limiting or preventing growth.

2. Two main crops were observed in 1959. The first and most significant crop developed prior to August 1. A second, lesser crop began about August 1 and persisted for the balance of the season.

3. Major shoreline accumulations of disintegrating algae occur as a result of a crop, having matured and become free floating, being carried in and held on shore by suitable winds and currents.

4. Local shore improvements may lessen the tendency to retain the algal masses. If it remains and disintegrates odor control by chemical means is impractical. The algal crop should be destroyed before large masses of growth occur.

5. Under the conditions of these tests, copper sulphate proved to be of little value in controlling Cladophora. Tribasic copper-sulphate was somewhat more effective while sodium arsenite and Hyamine were comparable and more effective. None of these chemicals achieved the removal of the alga. Growth was merely retarded.

6. "Aqualin", at concentrations of 5 and 10 p.p.m. (parts per million), cleared the plots of Cladophora and they remained clear for four weeks during which observations were taken.

Recommendations

In view of the observations and results which have been recorded above, the following recommendations are made:

1. The investigation should continue in 1960. To gain a complete understanding, observations should be made in May, on a weekly basis. More intensive work would be required throughout the balance of the season.

2. Fundamental studies with respect to the organism and its growth requirements, upon which any control program will ultimately depend, should continue.

3. The preliminary results obtained with algicides in 1959 must be checked and the studies enlarged upon with particular regard to:

(a) the proper timing of the control effort to provide maximum control of growth and of shoreline accumulations;

(b) the duration of the period of influence of any one treatment; and

(c) the determination of a suitable recommendation for algal control bearing in mind its feasibility both from the standpoint of economics and from the point of view of the mechanics of operation.

4. Subsequent to the completion of the 1959 investigation, information has been received concerning two chemicals which are recommended for the control of Cladophora. Endothal and TD-47 Herbicide, supplied by Pennsault Chemicals, should be tested in 1960.

5. In view of the interest shown in this and similar problems in natural waters and of the consequent demand for the widespread application of algicidal, herbicidal and other chemicals, it is expected that suitable procedures for the certification of these chemicals for the regulation of their use will be devised by the Commission.

In many instances, toxicity studies, beyond those conducted by industry, will be required.

INTRODUCTION

General Nature of the Problem

Fresh water species of the branching, filamentous, green alga Cladophora are of common occurrence in natural waters throughout Ontario and indeed throughout the world. The taxonomy of the genus is difficult and, at the moment, in need of clarification. Certain of the species are free floating but those with which this investigation is concerned grow attached to any available firm substratum.

Generally, the growth of this alga is not excessive, and its presence does not constitute a nuisance. Occasionally, however, in remote as well as in urbanized areas massive growths occur and subsequently accumulations of disintegrating, highly objectionable masses of organic matter result. Excessive growth of algae may occur in natural waters anywhere but the nuisance is greater where the concentration of mineral nutrients is increased by sewage effluents and by run-off waters from rich agricultural lands and other sources.

Nuisance conditions created by the decomposition of excessive growths of algae have occurred quite generally along the northern shores of Lake Erie for many years, and the related problems are familiar, particularly in the Crystal Beach area. In the past, certainly Cladophora has been encountered also in Lake Ontario but, in recent years nuisance conditions have not occurred. In the summers of 1957 and 1958, however, excessive growths did occur and the distressing results became the concern of a great number of property owners and municipal authorities along the lake front from Cobourg to Hamilton and beyond.

Conference on Problems Related to Cladophora in Lake Erie and Lake Ontario

On November 20, 1958, a conference was sponsored in Toronto by the Ontario Water Resources Commission to consider the conditions and problems associated with these objectionable growths of Cladophora in Lake Ontario particularly and in Lake Erie.

A panel composed of members of the Commission and others, chaired by Dr. A.E. Berry, heard reports from various interested parties and supplied information relative to various phases of the problem. The discussions have been abstracted, published and circulated by the Commission.

Organization and Purpose of the Investigation

In recognition of the magnitude and importance of the problems concerned, an investigation was undertaken for and by the OWRC of the conditions surrounding the excessive growths of Cladophora in Lake Ontario.

It was considered necessary and desirable to accumulate fundamental information concerning the alga and its basic growth requirements. Such studies would include the determination of species, the seasonal life-cycle fluctuations of the organisms concerned and its

growth responses to temperature, light, aeration, nutritional elements and other chemical and physical environmental factors. In a similar manner, the actual lake conditions under which the alga grows were of interest. Information concerning wave action, currents, drifts, water temperature and turbidity, and concentrations and distribution of nutrient mineral elements was recorded. Of importance as well was a survey to determine the actual extent of the algal meadows taking into consideration the depth at which the alga can satisfactorily grow and the distance from shore to which the growth, consequently, may extend.

In view of the urgency of the problem, however, it was determined that an immediate effort should be made first of all to devise a means of limiting or controlling the excessive growths of Cladophora and perhaps of lessening the related nuisance problems. The fundamental investigations, some of which have been mentioned above, were considered, momentarily, as being of secondary importance.

Various natural biological means of controls were considered and discarded in favor of the use of various algicidal chemicals; it was believed that some of them might reduce and control the alga even under the conditions which a large lake provides in terms of volume, mixing and consequent dilution. Various methods of clipping and harvesting the alga by mechanical means were considered and some thought was given to possible uses.

On June 22, 1959, an investigation concerning the chemical eradication and control of Cladophora was undertaken. The objective was to devise a method that could be recommended to interested municipalities or individuals. It was further proposed that, insofar as possible, physical and chemical environmental factors would also be investigated and fundamental features relative to the alga itself considered.

METHODS, MATERIALS AND PROCEDURES

Experimental Plots and Sampling Stations

For purposes of convenience it was decided to select Oakville as the center of the field survey and to limit our attention to the Port Credit-Oakville-Bronte region.

For the testing of algicidal chemicals, experimental plots approximating one half acre (200 by 100 feet) were marked off with buoys. The areas varied in depth from one to six feet. These plots were located one mile east of Bronte near Coronation Park and approximately three miles west of Bronte beyond the Pig and Whistle property. Areas were selected which were supporting a uniformly heavy growth of Cladophora.

Chemical sampling stations were established off Port Credit, Oakville and Bronte extending from the harbor mouth to points two miles off shore. On occasion samples were taken in certain of the test plots as well.

Water samples were taken and submitted to the Commission laboratories for nitrogen and phosphorus determinations. Bacterial counts were also made.

In the selection of experimental areas consideration was given to control measures which were being attempted by an Oakville organization, The Farm & Forest Research Corporation, on the lakefront in the immediate vicinity of Oakville.

Selection and Application of Algicidal Chemicals

A survey of the literature relative to algal control measures and a canvass of the agricultural chemical divisions of local chemical firms yielded very little information concerning chemicals suitable for controlling Cladophora under lake conditions. Two chemicals, which had been considered, were withdrawn from the market just before our investigation began.

The program for testing algicidal efficiencies included copper sulphate, tri basic copper sulphate and sodium arsenite. Supplies of these chemicals were made available by Chipman Chemicals Limited, Hamilton. A quarternary ammonium compound, supplied by Rohn & Haas Chemical Company under the trade name "Hyamine", was tested as an algicide and, to a limited extent, for odor control. Later, "Aqualin", an algicidal and herbicidal chemical, being developed by Shell Chemical Corporation, New York City, was obtained, supplied and applied by the Shell Oil Company of Canada.

Copper sulphate was applied in a crystalline form, using a Cyclone Seeder, on the theory that the crystals would sink to the bottom and go into solution in close proximity to the algal growth. The crystals, on one occasion, were coated with a finely powdered commercial clay in an effort to delay dissolution of the crystals. In one additional test the copper sulphate was applied as a solution. The tri basic copper compound was applied by towing a burlap "drag", con-

taining the chemical, on a line behind the boat. The sodium arsenite and "Hyamine" were applied with a hand sprayer while the "Aqualin" was applied by officers of the Shell Company using a suitable power sprayer.

Rates of Applications of Algicidal Chemicals

On July 28, 1959, three test plots in the vicinity of Coronation Park were treated with algicidal agents as follows:

Plot #1 - 3 p.p.m. copper sulphate crystals
#2 - 5 p.p.m. sodium arsenite under-water spray
#3 - 1½ p.p.m. tri-basic copper sulphate (equivalent of 3 p.p.m. copper sulphate)

The first crop of Cladophora to which these applications were made was nearing the end of its life and was dense with massive tangled plumes running up to three feet in length.

On August 13, 1959, six test plots in the Pig and Whistle area were treated as follows:

Plot #4 - 2 p.p.m. copper sulphate crystals
#5 - 4 p.p.m. copper sulphate crystals
#6 - 10 p.p.m. copper sulphate crystals
#7 - 10 p.p.m. tri basic copper sulphate
#8 - 3 p.p.m. sodium arsenite solution
#9 - 6 p.p.m. sodium arsenite solution

On the same day a plot in the Coronation Park area was treated with 5 p.p.m. of copper sulphate supplied as a spray.

At the time of application conditions were almost calm. The second growth Cladophora was six to eight inches in length.

On August 19, 1959, in co-operation with officials of the Shell Oil Company of Canada, "Aqualin", a Shell product, was applied as a spray to three plots in the vicinity of Coronation Park. By this time, of course, the initial crop had been replaced as in the above tests by a second crop of alga having filaments six to eight inches in length forming a solid cover over the rocky bottom.

Plot #10 - 10.5 p.p.m. "Aqualin"
#11 - 5.3 p.p.m. "Aqualin"
#12 - 2.7 p.p.m. "Aqualin"

At the time of application the lake was calm but a sub-surface drift in a southwesterly direction was noted which could account for a good deal of dilution of the chemical. The water temperature was 58°F and the pH 8.0.

This was the first application of "Aqualin" in Canada and the first application in open water to be made anywhere.

On August 20 two plots in the vicinity of the Pig and Whistle property were treated with "Hyamine", a quarternary ammonium compound.

Plot #13 - $2\frac{1}{2}$ p.p.m. Hyamine
#14 - 5 p.p.m. Hyamine

At the same time an application of this chemical was made to decomposing masses of Cladophora along the shore at the Pig and Whistle property.

Co-operation with the Geophysical Research Group

Through the co-operation of the Geophysical Research Group of the Research Division of the Department of Lands and Forests, arrangements were made for the use of a navy tug, the "Plainsville", which was obtained on July 14, and was subsequently berthed at Metro-Marine Basin in Bronte. In addition to serving as an operational base the tug was used for off-shore sampling and the dinghy and outboard for shallow water operations.

During our investigations some observations on drifts, water temperature and turbidity were made and reported to the Geophysical group. As this investigation proceeds other physical and chemical observations made in Lake Ontario by the Geophysical group will be available for our use.

On September 1 and 2, 1959, Dr. R. Dean, Department of Geology, University of Toronto, carried out diving operations in the Bronte area. Detailed information concerning the condition of the lake bottom and the extent of algal growth up to one-half mile off shore in water up to 30 feet in depth was obtained.

RESULTS OF THE CLADOPHORA INVESTIGATIONS

The General Nature of the Alga

The genus Cladophora includes about 160 species which are not well defined. A great deal of taxonomic study is required to provide for the certain identification of species of the genus. Both fresh water and marine species occur and the genus is widely distributed.

A member of the green algae, Cladophora grows usually as a branched, attached, filamentous form. In addition to the upright portion, attached species produce a prostrate, rhizoidal, basal growth which is usually perennial and from which regrowth of the alga may rapidly occur.

In most species which have been carefully studied there is in the life cycle a definite alternation of sporophytic and gametophytic plants which are identical in gross morphology but distinct in terms of their cytological detail and reproductive processes.

In most instances reproduction is accomplished most extensively by the formation of zoospores, involving reduction division. These are widely dispersed and form, by direct germination, haploid gametophyte plants. These plants produce gametes which, following sexual fusion, form resting spores. The latter germinate at once to produce diploid sporophyte plants thus completing the sexual cycle.

As a consequence, there is a constant possibility of renewal of growth at any time throughout the season. In addition, new growth may readily arise from the prostrate, perennial, rhizoidal base.

Most species require good aeration which is afforded in rapids and in areas where wave action is marked. It should be understood however that some species are capable of existence in quiet bodies of deep water.

The Actual Extent and Nature of the Algal Growth in Lake Ontario

Although it was not possible to conduct exhaustive studies of the lake front in general, the basic features relating to the Cladophora growth, as it occurred in the vicinity of Oakville from late June to mid September, were observed and useful deductions may be drawn.

It is obvious that the species of Cladophora with which we are concerned, grow only in areas where a suitable, firm substratum is available for attachment. On bed rock, the alga is able to establish itself only in cracks and crevices where, presumably, the reproductive cells have an opportunity to settle. Similarly the protected edges of large rocks support dense growths and, consequently, the most dense meadows are found in locations possessing a shingle or cobble bottom.

With respect to the universal distribution of this alga and the importance of a suitable attachment it may be noted that various

artificial sub-strata, such as piers and bridgework, soon become coated with the alga in areas where growth is otherwise absent. Marker buoys, during this investigation, became coated with Cladophora. At Rondeau Park, a single Cladophora-infested post was observed with no other algal stands within miles along the sandy beach.

In the Oakville area Cladophora was observed growing heavily in suitable areas from the water line to points in excess of six feet of water. Dr. Dean's diving operations indicated that, in areas ranging from six to 12 feet in depth, the amount of attached, growing Cladophora decreased rapidly. At 12 feet and beyond no significant growth was observed although quantities of disintegrating, free-floating masses were observed. Although no quantitative observations were made it was noted that in water ranging from 10 to 30 feet in depth, light was reduced at the bottom and a marked drop in temperature was noted in the bottom sediments.

In accordance with this evidence, considering depths approaching 10 feet, very extensive meadows may be expected along the shallower stretches of the shoreline. Certainly some of the meadows extend out 1000 feet from shore. Considering also the linear extent of the shoreline involved and the productivity of the alga per square foot, some appreciation of the magnitude of the control problem is attained.

Relationship of the Algal Growth to Mineral Nutrients

The results of chemical analyses have been summarized in Tables I and II. For complete details, refer to tables included in the appendix. It must be noted that the analyses obtained from samples taken at the Port Credit stations are not typical of the general shoreline since local municipal and industrial contamination strongly influence the results.

TABLE I

Mean concentrations of nitrogen compounds, total phosphates, and coliform bacteria at stations in Lake Ontario between July 21 and September 21, 1959. Bacteria expressed as coliforms per 100 ml. All other data in parts per million. (See appendix for complete records)

Location and distance from shore	Nitrogen compounds as N NH_3	Total Kjeldahl	Total Phosphates as PO_4	Coliform Bacteria
Port Credit				
at 100 feet	.86	3.2	2.13	5,200,000
250 "	.28	2.5	.27	110,000
500 "	.12	1.4	.15	73,000
1000 "	.09	.91	.11	6,500
½ mile	.05	.81	.08	810
1 "	.04	.85	.08	290
1½ "	.07	.61	.08	57
2 "	.03	.59	.08	190

TABLE I (Continued)

Location and distance from shore	Nitrogen compounds as N NH_3	Total Kjeldahl	Total Phosphates as PO_4	Coliform Bacteria
Oakville at				
100 feet	.07	.81	.12	1,800
250 "	.07	.78	.08	110
500 "	.06	1.1	.19	150
1000 "	.06	.38	.06	22
½ mile	.04	.45	.06	52
1 "	.05	.82	.08	180
1½ "	.04	.49	.05	1
2 "	.10	.87	.06	130
Bronte at				
100 feet	.06	.94	.17	110
250 "	.04	.47	.10	2,600
500 "	.05	.52	.06	3,000
1000 "	.04	.54	.04	9,200
½ mile	.06	.40	.06	29
1 "	.06	.52	.06	14
1½ "	.04	.52	.05	15
2 "	.07	.45	.05	5

TABLE II

Maximum and minimum concentrations, summarized from tables 1-3, of soluble phosphates and phenols at points in Lake Ontario from July 21 and September 21, 1959. (See appendix for complete results)

Location and distance from shore	Soluble Phosphates			Phenols		
	Number of samples	Maximum	Minimum	Number of Samples	Maximum	Minimum
Port Credit at						
100 feet	2	7.	.09	3	3	0
250 "	2	.09	.00	3	3	0
500 "	2	.09	.00	3	3	0
1000 "	2	.01	.00	3	3	0
½ mile	2	.01	.00	3	3	0
1 "	2	.01	.00	3	6	0
1½ "	2	.01	.00	3	2	0
2 "	2	.01	.01	3	2	0
Oakville at						
100 feet	2	.03	.00	3	3	0
250 "	2	.05	.00	3	3	0
500 "	2	.00	.00	3	0	0
1000 "	2	.00	.00	3	2	0
½ mile	3	.00	.00	4	3	0
1 "	3	.00	.00	4	4	0
1½ "	3	.00	.00	4	2	0
2 "	3	.00	.00	4	0	0

TABLE II (Continued)

Location and distance from shore	Soluble Phosphates Number of Samples	Maximum	Minimum	Phenols Number of Samples	Maximum	Minimum
Bronte at						
100 feet	3	.01	.00	4	0	0
250 "	3	.01	.00	4	0	0
500 "	3	.01	.00	4	0	0
1000 "	3	.01	.00	4	2	0
½ mile	3	.01	.00	4	3	0
1 "	3	.01	.00	4	3	0
1½ "	3	.01	.00	4	2	0
2 "	3	.01	.00	4	2	0

The mean concentrations of NH_3 at Port Credit show a steady decrease with increasing distance from shore. At Oakville a similar trend was noted but the mean concentration at the two-mile station was 0.1 p.p.m. as compared with .05 at 500 feet from shore. At Bronte there seemed to be no significant variation in mean concentrations at the stations studied.

Mean concentrations of total nitrogen at Port Credit show a decrease from 1.40 p.p.m. at 500 feet to .09 p.p.m. at the two-mile station. At Oakville stations no constant variation was observed and at Bronte only a slight tendency toward decrease in mean concentrations was observed with distance from shore. At the 100-foot station however a mean concentration of .04 p.p.p. was recorded while at two miles the mean was .45 p.p.m.

At Oakville and Bronte the mean concentrations of total phosphorus approximate .1 p.p.m. at the on-shore stations. On these ranges, the phosphorus content was reduced to approximately .05 p.p.m. at two miles. At Port Credit, beyond 500 feet, a similar reduction of approximately 50% was noted in the phosphorus analyses at two miles.

With the exception of the on-shore stations at Port Credit, no exceptionally high concentrations of these essential nutrient elements, nitrogen and phosphorus, were noted. It is significant however that the mean concentrations tend to decrease with increasing distance from shore. At the two-mile stations mean concentrations of one-half and one-quarter those recorded for near-shore locations may be observed in Table I

Minute quantities of nutrient chemicals are sufficient for the support of normal plant growth. Slight increases in the nutrient elements present may cause very large increases in the crop supported. Certainly the excessive growths of Cladophora observed in Lake Ontario indicate that the chemical nutrients are present in at least very adequate amounts. There is evidence of added enrichment of the waters at the shoreline relative to the chemical composition of the lake in general as indicated by sampling at the two-mile stations. In our present state of knowledge, however, it would be difficult to say whether or not any measure of control might be expected from a lowering

of the mineral content of the lake.

In view of the chemical uniformity of the lake in the area investigated it appears that the distribution of the growth is controlled mainly by physical factors related to the attachment of the organism.

Relationship of Algal Growth to Physical Factors

Throughout the period of the investigation temperature and current determinations were made from time to time. There are recorded in the following table. The current flow is indicated in feet per minute.

TABLE III

	Port Credit			Oakville			Bronte		
Date	Sfc. Temp.	Current	Bot. Temp.	Sfc. Temp.	Current	Bot. Temp.	Sfc. Temp.	Current	Bot. Temp
July									
14	--	---	--	60	---	--	60	---	--
16	--	---	--	--	---	--	67	---	--
20	--	---	--	--	---	--	66	---	--
29	70	---	--	66	---	--	65	---	--
Aug.									
4	60	SW-10	58*	62	Variable	60*	61	---	--
10	69	SE-15	64	68	SE-20	64	69	---	67
18	46	S-5	43*	49	W-WNW	48*	48	ESE-15	42*
19	--	---	--	--	10-25	--	--	---	--
19	--	---	--	--	---	--	58	---	--
24	67	calm	64	67	NE-1	65	67	NE-1	64
Sept.									
8	64	---	52	58	---	52	56	---	52
21	--	---	--	62	---	61	62	---	61

* Reading taken at 15 feet

The surface temperatures throughout the area were quite uniform during the period of investigation and approximated 60°F. As is shown by the records taken on August 18 and 19, however, marked and rapid fluctuations did occur and for the determination of rates of application of algicides, adjustments must be made according to the temperature prevailing at the time of treatment.

Some temperature gradient was noted in the lake but usually it amounted only to a few degrees.

Although temperature records are not presently available for the entire season, it is known that the alga undergoes appreciable growth in the early season and continues to thrive late in the fall. From December 28, 1959 to January 2, 1960, for example, the water intakes of the British American Oil Company were plugged by masses of Cladophora. It has been reported that these algal masses were healthy and fresh at that time and were carried in by a strong easterly wind.

The most extensive and rapid growth of Cladophora occurred in late June and during July. The more restricted growth, obtained in August and September, does not seem to be attributable to the water temperature. In view of its very universal distribution, the alga seems to be very tolerant of temperature conditions.

Water currents were studied mainly during reasonably calm periods. One set of records which were taken under storm conditions may be available at a later date. As is shown in Table III currents noted were either induced or influenced by the prevailing wind. Currents varying from zero to 25 feet per second (seven miles per day) were encountered.

In calm weather marked water currents were noted on the bottom when test plots were being observed. No measurements of these were made but such a phenomenon must be taken into account when determining the dilution factors relative to applications of algicidal chemicals. Such currents may also be important with respect to the agitation and aeration of the algal growth. In connection with the latter however wave action may be of greater importance.

Turbidity of the water might be a factor in limiting growth due to reduction of light intensity at lower levels. In general however a rock bottom which might be associated with low turbidity is essential for the establishment of attached species of Cladophora.

Seasonal Fluctuations in Growth of Cladophora

From observations elsewhere it is known that many algae including Cladophora, may be found growing at all seasons of the year. So far as this investigation is concerned observations were made only from late June to mid-September with some limited surveys in October.

When first observed at the end of June the Cladophora meadows were well developed. It is probable that considerable growth was attained in May although low water temperature may have retarded the rate of growth during the early part of the season.

Throughout July however the upright filamentous growth of Cladophora attained lengths of two to three feet and began to appear on the surface in suitably shallow water. Under the action of the water presumably, tangled plumes formed making the presence of the alga much more noticeable toward the end of July.

In general, during the early part of August, this first most massive crop of the season "matured" became free floating and disintegrated. As this massive growth of alga dispersed a second crop consisting of filaments one and two inches in length could be observed over the rock bottom. In subsequent weeks this crop never exhibited the vigor or extent of the earlier one. When last observed in detail on September 16 the growth in untreated areas had attained a maximum growth of approximately 12 inches.

General speaking, the significant growths of Cladophora and the subsequent nuisance conditions may be anticipated in July and early August. In the case of a particularly heavy infestation however distressing shore conditions may persist well into the fall. As has been mentioned above, accumulations of Cladophora plugged the water

intakes at the British American Oil Company on January 1, 1960.

The Nature, Occurrence and Control of Shore Accumulations

Masses of algal material accumulated and disintegrating along the shore is of course, the very essence of this problem. In Lake Ontario there is no great reason for concern about the healthy growth of the alga excepting in connection with some isolated cases of recreational use. When the alga accumulates and breaks down at the water's edge, in a band that may be 30 to 50 feet in width and several feet in depth, a nuisance condition results which can neither be minimized or ignored.

On the basis of our observations it is apparent that the alga becomes free-floating at the end of a growth cycle. Contrary to popular assumptions heavy wave action is not capable, in itself, of breaking down health, vigorous growths although it may be by such means that "mature" crops of Cladophora are cast up on the beaches. In general it would appear that this Cladophora thrives under violent physical action.

When the alga breaks away from its attachment it will remain healthy so long as it floats freely and does not stagnate in large masses. As a consequence, shore accumulations may occur for a limited time and be removed by appropriate wind and water action without ever developing any objectionable odor. Throughout the course of the investigation it was not uncommon to encounter large masses of Cladophora floating in the open lake. It is obvious that only a part of the algal mass arrives on shore and then only when suitable on-shore winds prevail.

If the alga is driven high on shore and is allowed to dry it forms a felt-like mass which is very resistant to break down and of course free of odor. If it remains as a mass in contact with the water and is closely packed, it may form an artificial extension of the beack, dry and brown on top, black, oily and incredibly offensive beneath. Once established such an accumulation may persist for a considerable period of time. It is relatively inoffensive in dry weather but with rain, storms or even high humidity it again produces an odor problem.

One application of Hyamine to such an accumulation was made to control the odor. While some influence might be exerted the fact impresses that there is little possibility of preventing or even diminishing the odor from any such reasonably extensive mass of disintegrating organic matter. It would involve complete and continuous sterlization.

Control of the offensive conditions associated with shoreline accumulations must involve either their prevention or their physical removal. The latter would present very great difficulties.

Diving operations revealed large masses disintegrating on the lake bottom. In water ranging in depth from 12 to 30 feet black, gaseous masses with the characteristic offensive odor were encountered on the bottom during the late season (September 1). Apparently this represents the fraction which has remained in deep water and which has ultimately settled.

In the light of these comments it seems probable that really obnoxious accumulations are derived in the main from the first, massive algal crop. These may persist and recur until September and October although at this late season the odor problem does not seem to be as great. Lower temperatures perhaps influence the rate of decomposition.

According to the observations the second more limited crop did not become free floating as a whole within the period of investigation although it may have produced local minor accumulations.

Control of the Alga by Chemical Means

The first applications of algicidal chemicals were made on July 28, 1959, but since this coincided with the end of a growth cycle, it was not possible to interpret the results. Subsequently the observation of the plots was often rendered difficult by the large floating masses of Cladophora that tended to obscure the bottom.

No indication of any effect on the alga was evident on August 4, one week after treatment but extensive algal accumulations were observed along the shore. As time went on, the first crop in treated and non-treated areas alike, becambe detached and the lake bottom, so far as the algal growth was concerned, became uniform. Meanwhile the second crop consisting of short, young filaments was developing.

TABLE IV

Summary of results of applications of algicides in Lake Ontario for the control of Cladophora sp.

Date of Application	Test Plot: Reference Number	Test Plot: Location of Plot	Application of Algicide: Chemical Used*	Application of Algicide: Concentration in p.p.m.	Results
July 28	1	near Coronation Park	$CuSO_4 . 5H_2O$ crystals	3	no control
" "	2	"	NA_2HAsO_3 solution	5	" "
" "	3	"	$CuSO_4 . 3Cu(OH)_2$	1.5	" "
Aug. 13	4	near Pig and Whistle Restaurant	$CuSO_4 . 5H_2O$ crystals	2	" "
" "	5	"	"	4	slight, temporary inhibition
" "	6	"	"	10	slight, inhibition of 30% of crop for 4 weeks

TABLE IV (Continued)

Date of Application	Test Plot: Reference Number	Test Plot: Location of Plot	Application of Algicide: Chemical Used*	Application of Algicide: Concentration in p.p.m.	Result
Aug. 13	7	"	$CuSO_4.3Cu(OH_4)_2$	10	eradication of 50% of the crop, remainder chlorotic and inhibited for 4 weeks
" "	8	"	$NA_2HA_5O_3$ solution	3	slight, inhibition of 100% of crop for 5 weeks
" "	9	"	"	6	moderate inhibition of 100% of crop for 5 weeks
" "	9	"	$CuSO_4.5H_2O$ solution	5	no control
Aug. 19	10	near Coronation Park	"Aqualin" solution	10.5	complete eradication of 100% of crop for 4 weeks
" "	11	"	"	5.3	severe inhibition of 100% of crop for 4 weeks
" "	12	"	"	2.7	moderate inhibition of 100% of crop for 4 weeks
Aug. 20	13	near Pig and Whistle Restaurant	"Hyamine" Solution (Active ingredient)	2.5	Inhibition of 100% of crop for 4 weeks
" "	14	"	"	5	"
" "	15	shoreline near Pig and Whistle Restaurant	"	Sprayed on shore accumulations for odor control, the result could not be assessed.	

* In the case of copper sulphate, sodium arsenite and "Aqualin", calculations are in terms of the compound. "Hyamine" applications are calculated on the basis of the active component and tri-basic copper sulphate applications were expressed in terms of copper sulphate (copper equivalents).

The results obtained using various applications of algicidal chemicals are summarized in Table IV. A discussion of these results follows:

(a) Copper Sulphate Applications

Applied at the rate of two p.p.m. copper sulphate crystals had no influence at any time and after a period of four weeks the alga was normal and healthy.

Four p.p.m. of copper sulphate produced some scattered killing of branch systems, particularly at their tips. Chlorosis and killing was apparent during the first three weeks but by four weeks following treatment (September 8) the alga was showing signs of recovery. By September 16 the test plots appeared to be essentially normal.

Ten p.p.m. copper sulphate produced a terminal kill over approximately 30% of the area within seven days (August 20). The basal portion of the growth, however, maintained a healthy appearance and the killing effect was more extensive where the growth was sparse and less so in the more dense areas. Throughout the four week period that followed there seemed to be some recovery. Actually, it would seem that the chlorotic tips were removed and the more healthy basal growth reduced by this means to a length of two to three inches were exposed.

Five p.p.m. copper sulphate applied as a solution had no recognizable influence on the algal growth.

(b) Tri basic Copper Sulphate

In general 10 p.p.m. of this chemical produced a more uniform chlorotic effect than copper sulphate crystals. Three weeks after treatment approximately 50% of the alga had been killed. The alga remaining was somewhat chlorotic and retarded in growth.

Tri basic copper sulphate appeared to be slightly more effective than copper sulphate at the same copper concentration.

(c) Sodium Arsenite Solution

The influence of sodium arsenite was similar to that of tri basic copper sulphate in that the chlorotic effect was uniform. At the close of one week a general chlorosis was apparent. The application of six p.p.m. was somewhat more effective than the three p.p.m. application. In subsequent weekly observations however the two test plots and the intervening check plots, apparently by diffusion, became uniform in appearance.

Five weeks after the treatment had been applied the growth in the arsenite treated areas was chlorotic and reduced to approximately two

to three inches.

Although there was no eradication the growth of the alga was retarded more by sodium arsenite than by either of the copper compounds referred to above.

(d) Hyamine Solutions

In two adjoining plots treated with two and one-half and five p.p.m. of Hyamine, a quarternary ammonium compound, an effect similar to that induced by sodium arsenite above was produced. The chemical seemed to become uniformally distributed by diffusion and mixing. At the close of three weeks it was estimated that the crop had been reduced by 60 to 70%. After five weeks (September 16) the plots, similar to those treated with sodium arsenite, exhibited chlorotic growth which was reduced to two or three inches in length.

(e) "Aqualin" Applications

It is possibly significant that the influence of applications of "Aqualin" was apparent less than 24 hours after the applications were made.

Applied at the rate of 2.7 p.p.m., "Aqualin" destroyed a significant portion of the growth rather than merely producing a chlorotic condition. An actual dissolution of the plant material seemed to have taken place.

At this rate of application however regrowth was apparent throughout the third and fourth weeks after treatment.

"Aqualin" when applied at the rate of 5.3 p.p.m. removed a remarkable portion of the alga. Large areas of the bottom were completely cleared within one week and only a few scattered clumps of Cladophora persisted on the edges of rocks and in crevices.

"Aqualin" applied at the rate of 10.5 p.p.m. removed all but a few brownish remnants during the first week. Subsequently for an additional three weeks during which observations were made this treated area remained perfectly clear of all growth and stood out in remarkable contrast to the surrounding untreated plots. It is noteworthy that with "Aqualin", very little diffusion or mixing occured. Apparently the killing action is rapid and the chemical is absorbed or dissociated before it has an opportunity to drift beyond the actual area of application.

DISCUSSION

The Occurrence and Distribution of Cladophora in Lake Ontario

It is evident that Cladophora is capable of growing anywhere in the portion of the lake studied where suitable attachment is afforded and where the depth and turbidity of the water is not too great. On a shore area with a uniform rock bottom Cladophora was found to decrease rapidly in areas covered by more than six feet of water and to be almost virtually lacking in ten feet of water. These limitations allow for the establishment of meadows extending 500 to 1,000 feet from shore in many of the areas studied.

On the basis of recorded monthly means, the maximum known variation in the water level in Lake Ontario is 6.2 feet. The water level during the summer of 1959 was 3.1 feet below the previous cyclic peak which was recorded in 1952. Extensive soundings were not undertaken during this investigation. It is obvious however that fluctuations in the water level would influence the lake area suitable for the growth of Cladophora. However it would seem the recent occurrence of excessive growths of Cladophora cannot be completely explained on this basis alone.

On the basis of surface and bottom lake temperatures recorded the water temperature does not seem to be a critical factor in the control of growth. With respect to the influence of water depth, lack of turbulence is probably more influential in limiting the growth of Cladophora than either temperature or light intensity.

The chemical analyses recorded in Tables I, II and III of the Appendix, do not indicate extremely high concentrations of nutrient elements at the on-shore stations. It is true however that the nutrient elements nitrogen and phosphorus are present at on-shore locations in amounts approximately double those found at the two-mile stations. This condition is undoubtedly due to rich run-off water along the shore and to the presence of municipal and industrial wastes.

For the growth of any plant, Cladophora included, the amount of essential elements required may be determined. Up to the point where a toxic condition results increases in available nutrients will induce increased growth. Accepting the fact that all other physical factors are suitable the degree of enrichment of the on-shore waters will have a direct effect upon the extent of algal growth.

The nutrient concentration is surely adequate for the support of excessive algal growth at the present time. With increased urbanization expected, the nutrient salts available to the lake will probably not diminish in the future. From the point of view of nutrient elements Cladophora must be regarded as a continuing problem in Lake Ontario.

To explain the fluctuations which are known to have occurred in the past with reference to excessive growths of Cladophora at these locations reference can be made only to known fluctuations in the water level. While the water level might influence the extent of the

growth it does not seem capable of explaining completely the presence or absence of nuisance conditions.

Our observations indicate that Cladophora produces at least two crops in any one growing season. The first crop was well established in mid-June and became free-floating around August 1st. The second crop, commencing in early August, remained healthy and attached at least until observations were discontinued in September. Subsequent information referred to above indicates the presence of nuisance accumulations of the alga as late as December and January.

During the period of investigation the first crop was much more extensive than the second. It is possible that water temperature may have an influence on the rate of growth.

The Importance of Shore Accumulations

In a location such as Lake Ontario the healthy growing Cladophora presents practically no problem. It is only when massive accumulations of free-floating alga becomes crowded in and disintegrates along the shore that a nuisance condition exists.

Kept moist nothing less than total sterilization will prevent the breakdown of this organic matter and the consequent distressing odor. Various odor control procedures have been suggested but it is unlikely that any will give success in actual practice.

In some areas these accumulating algae have been collected and removed mechanically. Even where this is attempted it is scarcely practical and in most areas along the shore conditions are such as to made these procedures quite impossible.

For practical results the prevention of these accumulations must be achieved. This will involve effective prevention or control of the growth of the alga before a large volume of growth has occurred. Otherwise an algicide, similar perhaps to "Aqualin", might be used in the killing of the alga bringing about its dissociation in situ and thereby obviating shore accumulations.

The observation that the alga breaks loose and becomes free floating as a result of the maturation of a crop rather than due to mechanical damage by storm is important in planning control measures. Most significant beach problems even those occuring in the fall, trace back and relate to the heavy first crop which occurs prior to August 1. In view of the fact that the second crop is by comparison not extensive, the control or destruction of the first crop might go a long way toward controlling the Cladophora problem in any one season.

The Effectiveness of Algicidal Chemicals

All of the available algicidal chemicals which were recommended for the control of Cladophora were tested. Most of these produced enough effect to warrant further study. None were investigated thoroughly enough to warrant their complete rejection.

Copper sulphate is well known for its toxicity to plant materials

but under the conditions prevailing in Lake Ontario it has proven unsatisfactory in concentrations of two and four p.p.m. Plots treated with 10 p.p.m. showed apical killing of the filaments with a consequent reduction in growth. The alga was at no time removed and at the end of five weeks the growth was green and plentiful.

Tribasic copper sulphate produced an effect on Cladophora which was limited but nontheless more extensive than that induced by copper sulphate.

Sodim arsenite and "Hyamine", a quarternary ammonium compound, were both more effective than either of the copper compounds. The growth was uniformally influenced and distinctly reduced in each case. The proper timing of treatment of the first crop of the season with these two chemicals might well be investigated further. It is possible that the crop might be reduced and contained within limits which would prevent subsequent objectionable shore nuisances.

Applications of "Aqualin" proved to be most interesting. Only this chemical, of all those tested was capable of bringing about a total removal of visible growth. For a period of four weeks at least, plots treated with five and 10 p.p.m. remained virtually barren.

It is apparent that "Aqualin" kills quickly and in low dilution. Thus the dilution problem which is so important a factor in a large body of water is minimized. Moreover the chemical is rapidly absorbed by organic matter of any kind and its residual effect is reduced rapidly.

Although a Canadian price for this experimental chemical is still not available plans are being made to place it on the Canadian market at a competitive price. Moreover other related chemicals are being investigated with a view to improving the general effectiveness of the product. Further study of "Aqualin", from many points of view, is certainly desirable.

Comparative Cost of Control Measures

No consideration of this phase of the problem has been possible up to the present moment for aside from the actual costs of material, some of which are not yet available, many other factors upon which the final cost picture will ultimately depend have not been determined.

Of greatest importance with respect to the actual growth program of the alga and to the cost and general effectiveness of treatment is the timing of the control effort. In turn the optimum time for treatment will depend on a number of factors, the influence of which can only be determined by experimentation.

To control the first crop and to prevent subsequent shoreline accumulations of disintegrating algae, an early application of algicide might be most effective. Moreover, the less the amount of organic matter present the less algicidal chemical is required. On the other hand the lower lake temperature in the early season might reduce the effectiveness of the chemical to the point where the application of an effective treatment would be too expensive.

Probably of greater importance in determining the cost of treatment is the period of effectiveness of any one application of a particular algicide. If this period is long enough it will be practical to use the algicide even though the initial cost is high.

APPENDIX TABLE I

Concentrations of nutrient chemicals, phenols and coliform bacteria at Lake Ontario stations near Port Credit from July 21 to September 21, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion and all other data in parts per million.

Date	Distance from shore	Nitrogen Compounds as N: NH_3 Test	Nitrogen Compounds as N: Kjeldahl Test	Phosphates as PO4: Total	Phosphates as PO4: Soluble	Total Phenols	Coliform Bacteria
July 21	100 feet		2.1	0.26			
	250 "		1.8	0.26			
	500 "						
	1000 "		0	0.13			
	½ mile		1.2	0.08			
	1 "		2.1	0.04			
	1½ "		0.0	0.01			
	2 "		0.3	0.01			
July 29	100 feet	0.05	0.5				
	250 "	0.05	3.0				
	500 "	0.04	3.8				
	1000 "	0.03	1.7				
	½ mile	0.05	1.0				
	1 "	0.06	0.4				
	1½ "	0.19	0.4				
	2 "	0.02	<0.05				
Aug. 4	100 feet	0.08	1.1	0.29			17,000
	250 "	0.08	0.4	0.32			33,000
	500 "	0.06	0.2	0.32			60,000
	1000 "	0.05	below 0.2	0.29			150
	½ mile	0.05	0.3	0.13			120
	1 "	0.04	1.2	0.09			0
	1½ "	0.04	0.2	0.13			0
	2 "	0.04	0.4	0.08			0
Aug. 10	100 feet	0.03	0.4	0.08			9,000
	250 "	0.02	0.5	0.05			58,000
	500 "	0.04	0.6	0.05			160,000
	1000 "	0.04	0.8	0.05			29,000
	½ mile	0.02	1.6	0.05			4,000
	1 "	0.05	0.5	0.05			630
	1½ "	0.03	1.2	0.21			40
	2 "	0.03	below 0.2	0.05			46
Aug. 18	100 feet	2.1	9.4	±1.			0
	250 "	1.4	2.3	0.73			60
	500 "	0.40	1.2	0.15			70
	1000 "	0.20	1.5	0.10			4
	½ mile	0.08	1.0	0.02			0
	1 "	0.04	0.2	0.20			0
	1½ "	0.11	0.5	0.03			0
	2 "	0.03	1.3	0.18			0

APPENDIX TABLE I (Continued)

Date	Distance from shore	Nitrogen Compounds as N: NH_3 Test	Nitrogen Compounds as N: Kjeldahl Test	Phosphates as PO4: Total	Phosphates as PO4: Soluble	Total Phenols	Coliform Bacteria
Aug. 24	100 feet	0.03	0.8	0.00		3	400,000
	250 "	0.27	9.9	0.00		0	48,000
	500 "	0.03	1.3	0.00		3	89,000
	1000 "	0.06	1.7	0.00		3	67
	½ "	0.05	0.5	0.12		3	15
	1 "	0.03	0.3	0.05		2	0
	1½ "	0.04	2.0	0.05		2	0
	2	0.04	0.8	0.18		2	2
Aug. 31	100 feet	0.22	2.0	0.26	0.09	0	11,000
	250 "	0.08	2.0	0.31	0.09	0	34,000
	500 "	0.21	2.2	0.26	0.09	0	17,000
	1000 "	0.18	1.3	0.10	0.01	0	0
	½ mile	0.05	0.6	0.10	0.01	0	0
	1 "	0.06	1.3	0.10	0.01	0	21
	1½ "	0.03	0.3	0.10	0.01	0	2
	2 "	0.05	0.6	0.05	0.01	0	0
Sept. 8	100 feet	3.5	8.9	13.	7.	0	31 x 10^6
	250 "	0.04	0.4	0.19	0.00	4	510,000
	500 "	0.04	0.2	0.09	0.00	0	110,000
	1000 "	0.04	0.1	0.08	0.00	2	10,000
	½ mile	0.06	0.3	0.04	0.00	2	700
	1 "	0.03	0.8	0.00	0.00	6	1,100
	1½ "	0.03	0.3	0.00	0.00	0	300
	2 "	0.02	1.2	0.01	0.00	0	1,100

APPENDIX TABLE II

Concentrations of nutrient chemicals, phenols and coliform bacteria at Lake Ontario stations near Oakville from July 21 to September 21, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion and all other data in parts per million.

Date	Distance from shore	Nitrogen Compounds as N: NH_3 Test	Nitrogen Compounds as N: Kjeldahl Test	Phosphates as PO4: Total	Phosphates as PO4: Soluble	Total Phenols	Coliform Bacteria
July 21	100 feet		0.3	0.01			
	250 "		1.5	0.05			
	500 "						
	1000 "		0.6	0.06			
	½ mile		0.6	0.06			
	1 "		2.7	0.36			
	1½ "		0.0	0.08			
	2 "		2.1	0.01			
July 29	100 feet	0.05	1.7				
	250 "	0.06	1.0				
	500 "	0.06	3.2				
	1000 "	0.06	0.9				
	½ mile	0.05	<0.05				
	1 "	0.06	0.8				
	1½ "	0.06	<0.05				
	2 "	0.06	1.3				
Aug. 4	100 feet	0.24	0.7	0.19			1,000
	250 "	0.07	0.3	0.11			550
	500 "	0.2	0.4	0.16			700
	1000 "	0.16	below 0.2	0.11			31
	½ mile	0.10	below 0.2	0.08			50
	1 "	0.10	below 0.2	0.08			18
	1½ "	0.05	0.8	0.09			0
	2 "	0.27	0.4	0.05			0
Aug. 10	100 feet	0.04	0.3	0.05			9,300
	250 "	0.04	0.4	0.08			60
	500 "	0.02	0.9	0.05			10
	1000 "	0.03	below 0.2	0.08			38
	½ mile	0.03	below 0.2	0.04			110
	1 "	0.04	0.6	0.04			46
	1½ "	0.02	1.1	0.04			7
	2 "	0.02	0.8	0.04			17
Aug. 18	100 feet	0.05	0.8	0.26			2
	250 "	0.04	1.2	0.04			0
	500 "	0.03	0.2	0.62			0
	1000 "	0.03	0.2	0.03			7
	½ mile	0.03	0.3	0.15			0
	1 "	0.06	0.2	0.03			0
	1½ "	0.05	0.2	0.03			0
	2 "	0.05	0.6	0.20			0

APPENDIX TABLE II (Continued)

Date	Distance from shore	Nitrogen Compounds as N: NH_3 Test	Nitrogen Compounds as N: Kjeldahl Test	Phosphates as PO4: Total	Phosphates as PO4: Soluble	Total Phenols	Coliform Bacteria
Aug. 24	100 feet	0.04	0.8	0.06		3	0
	250 "	0.04	0.6	0.05		3	0
	500 "	0.04	1.4	0.05		0	9
	1000 "	0.03	0.7	0.05		2	1
	½ "	0.04	0.7	0.05		3	0
	1 "	0.03	1.3	0.05		3	5
	1½ "	0.04	0.1	0.12		2	0
	2 "	0.16	0.5	0.02		0	4
Aug. 31	½ mile	0.05	0.7	0.01	0.00	0	4
	1 "	0.05	0.5	0.01	0.00	0	15
	1½ "	0.03	0.9	0.01	0.00	0	2
	2 "	0.05	0.8	0.01	0.00	0	0
Sept. 8	100 feet	0.02	1.7	0.03	0.00	0	300
	250 "	0.02	0.6	0.00	0.00	0	53
	500 "	0.03	1.2	0.00	0.00	0	200
	1000 "	0.06	0.3	0.04	0.00	0	55
	½ "	0.02	1.4	0.07	0.00	0	200
	1 "	0.03	1.1	0.04	0.00	0	1,200
	1½ "	0.02	0.7	0.00	0.00	0	0
	2 "	0.20	1.3	0.04	0.00	0	900
Sept. 21	100 feet	0.06	0.2	0.21	0.03	0	0
	250 "	0.22	0.6	0.21	0.05	0	0
	500 "	0.03	0.06	0.26	0.00	0	0
	1000 "	0.02	0.03	0.08	0.00	0	0
	½ mile	0.02	0.06	0.05	0.00	2	0
	1 "	0.03	0.06	0.05	0.00	4	0
	1½ "	0.02	0.6	0.03	0.00	0	0
	2 "	0.02	0.03	0.08	0.00	0	0

APPENDIX TABLE III

Concentrations of nutrient chemicals, phenols and coliform bacteria at Lake Ontario stations near Bronte from July 21 to September 21, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion and all other data in parts per million.

Date	Distance from shore	Nitrogen Compounds as N: NH_3 Test	Nitrogen Compounds as N: Kjeldahl Test	Phosphates as PO4: Total	Phosphates as PO4: Soluble	Total Phenols	Coliform Bacteria
July 21	100 feet		0.3	0.10			
	250 "		0.3	0.31			
	500 "						
	1000 "		1.2	0.05			
	½ mile		0.0	0.03			
	1 "		1.6	0.18			
	1½ "		0.9	0.08			
	2 "		0.3	0.21			
July 29	100 feet	0.03	<0.05				
	250 "	0.03	<0.05				
	500 "	0.05	0.7				
	1000 "	0.03	<0.05				
	½ mile	0.06	0.8				
	1 "	0.09	0.4				
	1½ "	0.04	0.5				
	2 "	0.04	0.2				
Aug. 4	100 feet	0.07	1.9	0.13			200
	250 "	0.10	0.6	0.07			470
	500 "	0.07	0.5	0.08			190
	1000 "	0.08	0.4	0.08			54
	½ mile	0.07	0.6	0.11			0
	1 "	0.14	0.2	0.11			0
	1½ "	0.04	0.2	0.07			0
	2 "	0.2	0.6	0.05			0
Aug. 10	100 feet	0.07	1.4	0.40			160
	250 "	0.06	0.9	0.32			2,500
	500 "	0.06	0.8	0.09			2,500
	1000 "	0.03	0.7	0.09			59
	½ mile	0.02	0.5	0.16			89
	1 "	0.04	below .2	0.05			3
	1½ "	0.04	1.4	0.05			16
	2 "	0.02	0.3	0.05			20
Aug. 18	100 feet	0.06	0.4	0.03			7,400
	250 "	0.03	0.3	0.03			14,000
	500 "	0.07	0.4	0.16			15,000
	1000 "	0.07	0.2	0.05			88
	½ mile	0.06	0.3	0.03			12
	1 "	0.04	0.3	0.04			31
	1½ "	0.07	0.3	0.02			1
	2 "	0.08	0.3	0.05			2

APPENDIX TABLE III (Continued)

Date	Distance from shore	Nitrogen Compounds as N: NH_3 Test	Kjeldahl Test	Phosphates as PO4: Total	Soluble	Total Phenols	Coliform Bacteria
Aug. 24	100 feet	0.03	0.9	0.52		0	1
	250 "	0.03	0.6	0.00		0	0
	500 "	0.03	0.7	0.00		0	0
	1000 "	0.05	0.7	0.00		0	0
	½ mile	0.02	0.6	0.00		3	0
	1 "	0.02	0.6	0.00		3	0
	1½ "	0.03	0.5	0.00		2	1
	2 "	0.02	0.7	0.00		2	3
Aug. 31	100 feet	0.03	1.2	0.01	0.01	0	2
	250 "	0.04	0.6	0.01	0.01	0	1
	500 "	0.03	0.7	0.01	0.01	0	2
	1000 "	0.03	1.2	0.03	0.01	0	64,000
	½ mile	0.03	0.4	0.03	0.01	0	0
	1 "	0.04	0.3	0.05	0.01	0	16
	1½ "	0.03	0.6	0.01	0.01	0	90
	2 "	0.11	0.4	0.01	0.01	0	6
Sept. 8	100 feet	0.08	1.7	0.03	0.00	0	30
	250 "	0.03	0.7	0.03	0.00	0	1,000
	500 "	0.04	0.3	0.03	0.00	0	3,000
	1000 "	0.03	0.4	0.00	0.00	2	100
	½ mile	0.20	0.3	0.05	0.00	0	100
	1 "	0.10	1.1	0.00	0.00	0	46
	1½ "	0.03	0.1	0.08	0.00	2	0
	2	0.03	1.2	0.01	0.00	0	0
Sept. 21	100 feet	0.12	0.65	0.05	0.00	0	2
	250 "	0.03	0.2	0.05	0.00	0	0
	500 "	0.03	0.06	0.05	0.00	0	0
	1000 "	0.03	0.1	0.05	0.00	0	0
	½ mile	0.03	0.06	0.05	0.00	0	0
	1 "	0.03	0.06	0.05	0.00	0	0
	1½ "	0.03	0.2	0.05	0.00	0	0
	2 "	0.03	0.06	0.05	0.00	0	1

APPENDIX TABLE IV

Concentrations of nitrogen and phosphorus nutrient compounds in various algicidal test plots.

TREATMENT AREAS

Date	Location	Nitrogen as N NH_3	NO_3	Total Kjeldahl	Phosphates as PO4 Total	Ortho
July 21	Test area 1			1.0	0.05	
	2			2.4	0.16	
	3			0.3	0.06	
July 29	Test area 1	0.09		0.8		
	2	0.04		3.0		
	3	0.06		0.9		
Aug. 4	Test area 1	0.06		0.9	0.11	
	2	0.24		0.5	0.07	
	3	0.18		0.5	0.07	
Aug. 10	Test area 1	0.9		<0.05	0.05	
	2	0.8		< .05	0.05	
	3	0.5		< .05	0.05	
Aug. 18	New plots W. Bronte					
	4	0.03		1.2	0.05	
	5	0.03		0.3	0.10	
	6	0.05		1.8	0.08	
	7	0.03		0.3	0.05	
	8	0.03		0.8	0.16	
	9	0.03		0.8	0.08	

APPENDIX TABLE V

Concentrations of nitrogen compounds, total phosphates, phenols and coliform bacteria at miscellaneous stations in Lake Ontario, between July 21 and September 8, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion, all other data in parts per million.

Date	Location of Station	Nitrogen Compounds as N: NH_3 Test	Nitrogen Compounds as N: Kjeldahl Test	Total Phosphates as PO_4	Phenols	Coliform Bacteria
July 21	Mouth of Credit River		1.3			
	" " Oakville Creek		1.2	0.21		
	" " Bronte Creek		2.1	0.10		
Aug. 4	Mouth of Credit River					1,000
	" " Oakville Creek					300
	" " Bronte Creek					110
Aug. 10	Mouth of Credit River					2,600
	" " Oakville Creek					12,000
	" " Bronte Creek					94
Aug. 18	Mouth of Credit River	0.2	0.7	0.91		
	" " Oakville Creek	1.0	1.5	0.65		22,000
Aug. 24	Mouth of Credit River	0.03	0.1	0.12	3	150
	" " Oakville Creek	0.30	1.9	0.31	3	710
	" " Bronte Creek	0.05	0.2	0.05	3	20
Aug. 31	Mouth of Oakville Creek					400
	" " Bronte Creek					3
Sept. 8	Mouth of Credit River					1,800
	" " Oakville Creek					8,600
	" " Bronte Creek					3

Cladophora INVESTIGATIONS

\- 1960 -

A Report of

Observations on the Nature and Control of
Excessive Growth of *Cladophora* sp. in
Lake Ontario and Lake Erie

Duncan A. McLarty

The
Ontario Water Resources
Commission

R-62-1

This project was carried out by the Ontario Water Resources Commission under the direction of John H. Neil, Supervisor, Biology Branch of the Commission's Division of Laboratories. Dr. Duncan A. McLarty, Department of Botany, University of Western Ontario, was in charge of the field work.

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TABLE OF CONTENTS

SUMMARY AND RECOMMENDATIONS

Summary

1. The period and extent of growth in Lake Ontario in 1960 was similar to that observed in 1959. Cladophora was first observed arising from a prostrate, perennial, basal structure on the rocky substratum on May 25. Subsequently, a uniform growth was produced in suitable areas bearing up to approximately six feet of water. The first crop matured and floated free late in July and was replaced by a second crop which persisted beyond the period of observation in the fall.
2. The degree of growth was much less in 1960. In most areas the filaments did not exceed six inches in length at any time. Shore-line accumulations were minimized but not eliminated by virtue of the large area of growth involved and by the drifting together of material from distant points.
3. It is difficult to explain the marked reduction in growth in 1960. It was observed, however, that the lake was very turbid throughout the season; radiation was much reduced in 1960 while rainfall was more abundant. The latter feature may, in terms of dilution of nutrient minerals in water along the shore, be related to the lower nitrogen and phosphorus content of the shore-line samples taken in 1960.

4. In Lake Erie, Cladophora was found only on suitable exposed rocky reefs which were somewhat removed from shore. Although the water was clear in these areas, the Cladophora appeared no more green and healthy than in the turbid waters of Lake Ontario and the extent of growth was similar to that in Lake Ontario. The ability of this alga to eventually contaminate shore-lines which are obviously far removed from the source was clearly demonstrated.

5. Applications of Aqualin were made at the rate of 3,6 and 9 ppm in Lake Ontario. Although much killing occurred in the test areas, the individual plots were not clearly recognizable as they were in 1959 under similar conditions. Diffusion or current action obviously had distributed the algicide over a considerable area. Observation of the Plots was difficult due to persistent rough weather and to conditions of high turbidity.

   In Lake Erie, applications of Aqualin at rates of 2 and 6 ppm had no significant influence. It is presumed that wave action on the very exposed site diluted the chemical below its effective level of concentration.

6. In Lake Erie, copper sulphate, sodium arsenite and Endothol were applied with no significant result. TD-47, however, applied at the rate of 0.5 ppm, achieved complete control on one acre of Cladophora.

RECOMMENDATIONS

In view of the results obtained and reported, the following recommendations are made.

1. This investigation should be continued in order to capitalize upon results already obtained. The factors contributing to and controlling the growth of <u>Cladophora</u> under conditions found in large bodies of water are almost virtually unknown aside from our own observations. Seasonal variations in physical and chemical environmental factors may only be determined by and evaluated, in terms of algal production, on the basis of observations taken over a period of years.
2. For the testing of algicidal chemicals, representative areas which are capable, nonetheless, of some confinement and control must be sought otherwise, in open water locations in the Great Lakes, larger test areas must be employed to minimize the dilution factor which is introduced by diffusion, currents and wave action.
3. Laboratory and field experiments, designed to provide concrete fundamental knowledge concerning the biology of <u>Cladophora</u>, upon which its growth and the ultimate intelligent control of its growth will depend, must be undertaken. Such information is almost totally lacking at the present time.
4. In the course of such controlled experimentation,

approaches to control meausres, other than by classical chemical means, should be considered. Biological means of control, for example, should not be disregarded.

5. In conjunction with these studies, information concerning the general properties and characteristics of algicidal and herbicidal chemicals, currently being produced and promoted for use in natural waters, should be determined to enable the Commission to certify these chemicals and regulate their future use.

INTRODUCTION

During the summers of 1957 and 1958, excessive growths of Cladophora occurred on rocky out-crops along the north-westerly shores of Lake Ontario. When the crop matured and floated free, large masses of disintegrating alga material accumulated along the shoreline. As a result, the lake front was rendered almost uninhabitable for a period of time and the resultant odor was apparent for as much as one mile inland. Lake shore municipalities and private owners were concerned and their problem was brought to the attention of the Ontario Water Resources Commission. Field studies which were conducted under the direction of the Commission in 1959, have been reported and the studies have been continued in 1960.

Initially it was proposed to test all available algicidal chemicals with respect to their effectiveness in the control of Cladophora production and with regard to the dangers and problems

associated with their use. The primary purpose of the investigaion was to select, if possible, a compound which might be safely recommended for use by interested municipalities or individuals.

Moreover, the investigations conducted in 1959 demonstrated the need for fundamental information concerning the biology of the organism itself and of the chemical and physical features of the lake environment upon which excessive growths may depend.

Accordingly, preparations were made for intensive studies of the growth and accumulation of Cladophora in the immediate vicinity of Oakville and Bronte and of chemical means of control. Subsequently, the studies were extended to include investigations at various points in Lake Erie.

METHODS, MATERIALS AND PROCEDURES

Basic Equipment

Sampling stations were marked by anchored wooden spars. Test plots, for application of algicidal chemicals, were measured and buoyed in areas bearing one to six feet of water. Fish net floats were used as markers for the plots which were one half of one acre in extent.

A 16-foot aluminum boat, powered by a 18 horse power outboard motor, was used for all water sampling and spray applications. This boat, which was provided by the Commission, was equipped with a trailer to permit its use in many locations.

A gasoline powered centrifugal pump was prepared for the

application of chemicals in solution. The pump was equipped with a dual intake and attached to a fourteen foot boom. The boom was mounted on the stern of the boat and supplies with four submerged nozzles. Concentrated solutions were metered in on the suction side of the pump, diluted with a large volume of lake water and applied to the lake bottom over a sixteen foot strip. By this means applications were made uniformally and with reasonable rapidity.

Applications of crystalline materials were made using a Cyclone Seeder.

Water samples were taken at various distances from shore to be analysed in the laboratories of the Ontario Water Resources Commission.

Algicidal Chemicals Tested

It is probably significant that, in areas where aquatic weed and algal control programs have been carried out for more than a quarter of a century, the classical compounds, copper sulphate and sodium arsenite are still used almost exclusively for routine, extensive control operations. In a compilation of information derived from recent research on aquatic weed and algal control in the United States, Mr. Kenneth M. Mackenthun reports,[1] in addition to results on more recently developed compounds the continued reliance upon these copper and arsenic compounds in control measures applied in the state of Wisconsin.

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[1] Mackenthun, Kenneth M., 1959 Summary of Aquatic Weed and Algae Control Research and Related Activities in the United States. Wisconsin Committee on Water Pollution.

The toxicity of copper in respect to plants generally is well known and applications of copper sulphate, particularly as a control for planktonic algae, have been made for many years.

Arsenic Trioxide (sodium arsenite) has been applied widely in the control of rooted aquatics and, in some instances, for the control of certain green filamentous algae.

Chemicals of more recent origin are available for use as herbicides and algicides. In many cases, however, their effectiveness under various specific conditions is not known and their toxicity to fish and other wildlife is often only partially determined. In most cases the cost relationships are such that, for general application, they will be able to compete economically with the classical compounds only if they prove to be much more efficient.

Endothol, prepared and supplied by the Pennsalt Chemicals Corporation, is the disodium salt of 3, 6 endoxohexahydrophthalic acid. Used as an herbicide originally, it has been suggested for the control of aquatic growths since 1956. It is available in liquid and granular formulations and has been reported as effective against algae and aquatic weeds in concentrations ranging from 1-3 ppm.

TD-47 herbicide is another derivative of the endoxohexahydrophthalic acid which available for experimental use only. Produced originally as a pre-emergent herbicide, it is suggested as an aquatic herbicide to be used at concentrations ranging from 0.25 to 1.0 ppm.

Aqualin, a solution containing 85% acrolein, has been prepared and promoted by the Shell Oil Company. Although its properties require special care in handling and its toxicity is such that universal application may not be possible, the effectiveness of this chemical in the control of aquatic growths, both rooted and algal, is most encouraging.

For the adequate and economic control of aquatic weeds and algae in large systems, such as Lake Ontario, an exceedingly effective, quick acting chemical with low toxicity to wild life is required to overcome the massive dilution effects of wave and current action.

Experimental Plots and Sampling Stations.

In Lake Ontario, algicide testing plots were selected in the area between Coronation Park and Bronte. Arrangements were made with a local commercial applicator that no operations would be carried on in this vicinity which would in any way influence the testing procedures of the Commission. One half acre plots were used in this case.

In Lake Erie, plots were selected on the southerly side of Mohawk Island where, on extensive rocky ledges two miles from the main shore, uniform beds of Cladophora were observed. On the southerly side of Stoney Island, located about one mile from shore, other plots were established. In each case, one acre plots were used.

Chemical samples were taken at shore line stations either side of Bronte. One station was located fifty feet from shore

one mile west of the Pig and Whistle Restaurant in an area used for algicidal chemical tests in 1959. A second station was located fifty feet from shore half way between Bronte and Coronation Park. At the westerly boundary of Coronation Park sampling stations were established 100, 250, 500 and 1000 feet from shore with additional stations one half and one mile from shore.

Applications of Algicidal Chemicals

On June 7, 1960, three test plots were treated in the vicinity of Coronation Park with the co-operation of members of the Shell Oil Company of Canada.

Plot #1 - 3.0 p.p.m. "Aqualin"

Plot #2 - 6.0 p.p.m. "Aqualin"

Plot #3 - 9.0 p.p.m. "Aqualin"

At the time of application the lake was clear and calm. The water temperature was 57°F., and the rocky bottom was covered by a uniform growth of Cladophora approximately four inches in length.

On August 11, 1960 in co-operation with members of the Shell Oil Company of Canada, applications were made on one acre plots off Mohawk Island in Lake Ontario.

Plot #4 - 2.0 p.p.m. "Aqualin"

Plot #5 - 6.0 p.p.m. "Aqualin"

At the time of application the water temperature in the plots was 71°F and the water was crystal clear. The rocky bottom was covered with a uniform, continuous growth of Cladophora

approximately six inches in length. Excepting when occurring at the water line on large, emergent rocks, the alga appeared pale and did not display the deep green colour usually associated with the alga.

During the period of application a stiff southwesterly breeze got up for a time and rough water over the ledge almost forced the discontinuance of operations.

On August 18, 1960, applications of algicidal chemicals were made at Stoney Island.

Plot #6 - 10.0 p.p.m. copper sulphate crystals

Plot #7 - 10.0 p.p.m. sodium arsenite solution

The water temperature in the plots was 73°F and the bottom was covered by a dense growth of Cladophora which was four to six inches in length. The pale, yellowish condition of the alga persisted. The lake was calm.

On August 24, 1960, applications of Endothol and a liquid preparation of TD-47 were made on one acre plots off Mohawk Island. Of these chemicals supplied by Pennsalt Chemicals Corporation, the latter is a recently developed compound which is available only in limited amounts for experimental purposes.

Plot #8 - 2.0 p.p.m. Endothol

Plot #9 - 0.5 p.p.m. TD-47 solution

At the time of application the water temperature was 70°F and the lake was calm. The Cladophora growth was dense and uniform throughout the plots. It approximated six inches in length and showed the yellowish colour which characterized the growth as

it was observed in 1960.

Observations on Algal Growth and Shore Accumulation

From mid-May to early September the condition and growth of Cladophora in Lake Ontario was observed, Shore conditions were noted periodically from Port Credit to Burlington and, in relation to reports of commercial control procedures, detailed observations were made of shore line accumulations of Cladophora on July 15 and August 26.

Periodically throughout the summer observations were made on south shore of Lake Ontario near Stoney Creek with reference to Cladophora production.

On July 26, 1960 observations were made of the Lake Erie shore line, and of the lake from Cedar Crest, west of Port Colborne to Humberstone Community Beach. Throughout August and in early September observations and tests were made on Lake Erie in the vicinity of Lowbanks, a small community west of Port Colborne.

RESULTS OF THE CLADOPHORA INVESTIGATIONS

Observations of Lake Conditions

In Lake Ontario, in the Oakville-Bronte area at least, high turbidity persisted throughout the season. To some extent, at points east of Bronte this condition might be attributed to heavily silted waters observed flowing into the lake at Bronte and being carried eastward in the prevailing drift. It should be recorded, however, that west of Bronte in the vicinity of Burlington and east of Oakville conditions were not significantly different. For the most part the bottom was quite invisible in areas with

more than even one foot of water.

On a few occasions the water was clear and the bottom conditions readily discernible. The growth of Cladophora was uniform but never extensive in length and usually heavily silted. This condition undoubtedly contributed to the pale, yellowish appearance which characterized the algal growth in 1960.

In the course of the summer, Cladophora filaments did not attain a growth of more than a few inches in any of the areas under observation. The initial growth in early June was rapid and widespread but the total production in 1960 was far below that experienced in 1959. Difficulties associated with the observation and assessment of plots before and after chemical treatment and the almost static condition of the algal growth, combined to create a situation in Lake Ontario which was very unfavourable for algal control investigations.

In Lake Erie the circumstances associated with Cladophora production differ in one significant way from those prevalent in Lake Ontario. The shore line in the Port Colborne district, for example, consists of bays with sandy, silted bottoms in which various rooted aquatics are established but where no Cladophora occurs. Between the bays, however, rocky points extend out into the lake, sometimes a great distance, on which the beds of Cladophora are found. At Mohawk Island such a series of rocky ledges extends several miles from the island in a southeasterly direction. In a similar fashion shoals occur in the vicinity of Stoney Island which create large areas suitable for Cladophora

production.

These areas, remote from shore, were not subject to silting, as has been described for Lake Ontario locations. The algal growths, however, appeared pale and yellowish and were limited in linear development as has already been described for Lake Ontario growths in 1960.

Bearing in mind that only a fraction of the *Cladophora* crop is required to create a problem along the shore, these remote, extensive beds may represent a serious source of trouble even when the growth is actually minimal. Moreover, in these exposed positions, rough water often occurs which stimulates *Cladophora* production but which makes the chemical control of the alga very difficult by promoting a rapid dilution of the algicide.

Throughout the period of investigation in 1959 the surface temperature of Lake Ontario fluctuated around 65°F and, at times late in the season, dropped to as low as 48°F.

TABLE I

Meteorological Data taken at Toronto Ontario.

		May	June	July	Aug	Sept.
Mean Air Temperature F	1959	58	68	73	74	66
	1960	56	65	69	69	65
	Normal	55.2	65.6	70.7	68.8	61.2
Total Precipitation	1959	1.19	1.14	1.23	1.35	3.79
	1960	5.29	2.43	4.38	1.23	0.31
	Normal	2.65	2.70	3.23	2.39	2.67
Bright Sunshine hours	1959	247.8	252.5	298.1	251.3	222.4
	1960	144.0	265.1	307.1	291.2	181.1
	Normal	222.8	265.3	289.4	260.8	194.0
Radiation B.T.U./ft^2	1959	58287	61510	66037	53888	41605
	1960	44007	60771	62871	57312	38979
	Normal	38088	51097	59911	57821	51999

Observations Concerning General Meteorological Conditions

As shown in Table I the hours of bright sunlight, recorded for Toronto, were greater in June, July and August, 1960, than in the corresponding months in 1959. It may be noted that in May, 1960, the hours of bright sunlight were less than normal and much less than those recorded for May, 1959. The total radiation recorded for May to September in 1960 was uniformally less than in 1959 excepting for August. During this month the radiation was less than normal but greater than the radiation recorded in August 1959. Associated with these records are the mean air temperatures which, in 1960, were uniformally less than corresponding air

temperatures recorded for 1959.

These data, when considered along with the conditions of high turbidity which were experienced in Lake Ontario in 1960, suggest that a reduction in solar radiation may explain, in part, the general reduction in growth of Cladophora in Lake Ontario during 1960.

The meteorological records show, in addition, that precipitation was generally higher than normal in May, June, and July, 1960, and much higher than in the corresponding period in 1959. In August and September, however, the rainfall was less in 1960 than in 1959. The heavier precipitation early in the growth period, and the consequent dilution of the lake water along the shore particularly, may be associated with the generally reduced chemical nutrient content of lake samples taken from these locations in 1960.

Algal Growth and Shore Line Accumulations

The first filamentous growths of Cladophora were observed arising from the yellowish, squamous, perennial base on May 25, 1960. At that time the filaments consisted of less than a dozen cells. In the subsequent two week period, up to June 7, 1960, when first applications of algicidal chemical were made, the alga attained a length of four to six inches. Subsequently, however, it made very little growth and appeared to be essentially quiescent. The total algae production in 1960 was significantly less than in 1959.

As a consequence, the algal accumulations along the shore, creating nuisance conditions, were at a minimum in 1960. No massive accumulations were observed. Minor washings were observed on June

20. These were comprised of very short fragments of Cladophora. Observations, along the shore from near Port Credit to near Burlington on July 15 and August 26, 1960, which were made with reference to reports in the press by a local commercial applicator, provided useful information. While no large accumulations were observed on July 15, conditions seemed to be slightly better in the Oakville area where control measures had been commercially applied. On August 26, however, the situation was quite reversed. The position of the accumulations indicated that wind direction, currents, and natural and artificial obstructions along the shore determine the location of accumulations of algae. As in Lake Erie, the algal material may be carried some distances from point of origin.

On July 26, local accumulations were observed along the shore of Lake Erie in the vicinity of Port Colborne. At two locations mechanical removal had been attempted but it was found to be quite impractical because the algal material continued to accumulate under the influence of on-shore winds. At Cedar Bay, Silver Beach and Humberstone Community Beach, where commercial control measures were said to have been applied, varying conditions existed which were in no way different from those observed in untreated areas west of Port Colborne.

On August 25, shore line accumulations were reported to have occurred during the previous two week period on the south shore of Lake Ontario in the vicinity of Stoney Creek. The area was quite clear at the time and no further information was available.

TABLE II

Summary of results of applications of algicides for the control of Cladophora sp.

Date of Application	Test Plot: Number	Test Plot: Location of Plot	Application of Algicide: * Chemical Used	Application of Algicide: Concentration in ppm	Result
June 7	1	Near Coronation Park	Aqualin	3	Complete eradication in irregular areas. Individual plots not discernible
June 7	2		Aqualin	6	Buoys removed by storm
June 7	3	"	Aqualin	9	Turbidity difficulties.
Aug. 11	4	Mohawk Island	Aqualin	2	No control
Aug. 11	5		Aqualin	6	No control
Aug. 18	6	Stoney Island	$CuSO_4 5H_2O$ crystals	10	Terminal burning on 50% of crop. Mainly recovered in three weeks.
Aug. 18	7		NA_2HAsO_3	10	Temporary burning Complete recovery in three weeks.
Aug. 24	8	Mohawk Island	Endothol	2	No control
	9	"	TD-47	0.5	90% eradication after two weeks

* In the case of copper sulphate and "Aqualin" concentrations are calculated in terms of the compound. Sodium arsenite, Endothol and TD-47 are calculated in terms of the active component.

Control of the Alga by Chemical Means

The results of applications of algicidal chemicals are summarized in Table I.

Due to high turbidity and storms it was not possible to observe the plots for two weeks following applications of Aqualin on June 7. When observed on June 20, the markers had been carried away and the plots were not discernible. The alga, however, had been eradicated over a considerable area in the vicinity of the plots. It was apparent that a good deal of diffusion of the chemical had occurred.

Applications on plots 4 and 5 at Mohawk Island produced no significant result. It should be noted, however, that, due to difficulties with respect to calibration of the pumps, slightly less that 2.0 p.p.m. was applied on plot 4 and a result was not anticipated. Rough lake conditions, which developed during the application, may well have diluted the chemical severely before any influence on the growth was possible.

Copper sulphate and sodium arsenite, applied at the rate of 10 p.p.m., had very little significant and permanent effect. Killing was confined to the terminal branches of approximately 50% of the growth. After three weeks, the green, unaltered basal growth was again exposed by the sloughing off of the dead, terminal filaments.

Endothol, applied at the rate of 2.0 ppm had only a temporary influence on the Cladophora but TD-47 produced a 90% kill when applied at the rate of 0.5 p.p.m.

It should be emphasized that all of the experimental plots in Lake Erie were in very exposed locations which are subjected to great mixing when even moderate wave action occurs. The positive action of TD-47 in this type of location is suggestive of very great efficiency.

EXPERIMENTS INVOLVING ARTIFICIAL FERTILIZATION OF NATURAL WATERS

With respect to excessive algal growths it is often assumed that increased mineralization of streams and lakes, by run-off waters from rich agricultural land and by the discharge of domestic and industrial sewage effluents, is the determining factor. In the absence of proof, however, this remains purely an assumption.

If, in a barren area otherwise suitable for Cladophora production, applications of various fertilizer salts would induce the growth of the alga, evidence of the importance of increased concentrations of nutrient salts would be obtained. Consequently, some experiments were undertaken by Mr. Neil in suitable locations in Georgian Bay.

In the vicinity of Methodist's Point, a rocky area was selected where no Cladophora was observed. The alga was observed, however, at various locations remote from the test area. Stations were established at points about one half mile apart in water approximately two feet in depth. Applications of nutrient elements were made on June 26, by anchoring bags of commercial fertilizer at various stations, as listed below, and allowing the salts to dissolve over a period of time.

1. Aeroprills (Cyanamid of Canada Ltd.) - 33.5% Nitrogen
2. Super phosphate (Canadian Industries Ltd.) - 20% active
3. Turf Special (Canada Packers Ltd.) -10-6-4 analysis
4. Milorganite - 5.5-4-0 analysis

When examined on July 29, all of the chemicals, with the exception of some super phosphate, had dissolved. Additional applications were made in the same manner as described above.

Cladophora was not induced to become established in any of the areas to which fertilizer were added. With the exception of the appearance of a growth of an unspecified green alga in the vicinity of the super phosphate station, the applications of nutrient elements produced no apparent result.

In such an experiment, of course, only a positive result would be significant. The absence of any result whatever may depend upon one or several of many possible factors. For example, the concentration of the nutrient elements attained may not have been high enough to be significant or other environmental factors may have been limiting. Reproductive units of Cladophora may have been carried into the area from the distant growths or additions of these nutrients may not be a determining factor in the establishment of growths of Cladophora. It should be recalled, however, that artificial fertilization is practised to increase the productivity of fish ponds by stimulation of planktonic growth.

It is possible that similar experiments, conducted under different circumstances, might yield interesting results concerning

the relationship between levels of concentration of nutrient salts and excessive algal growth.

Chemical Analyses of Lake Samples

The results of chemical analyses and bacteriological counts, made on water samples taken from Lake Ontario in 1960, are recorded in Tables I to VI of the appendix. Averages, maximum and minimum and median values are recorded for each individual station and average concentrations and counts for each sampling period throughout the season are included.

The nitrogen and phosphorus concentrations, with the exception of ammonia tend to decrease throughout the season (Table III). More significantly, perhaps, ammonia and total nitrogen concentrations decrease from June 22 to July 20, attain a second maximum early in August and then decline again to the end of the sampling period. Total and soluble phosphorus concentrations show a similar pattern, but the second maximum concentration occurs earlier, on July 27. These patterns may be related to the crop cycle noted for Cladophora.

When the mean concentrations of nitrogen and phosphorus compounds, at all stations within 100 feet of shore, are compared with the mean concentrations in all off-shore samples, some evidence of shoreline accumulations of nutrient elements is obtained. In Table III these calculations are summarized along with early season and late season average means.

TABLE III

Variation in average mean concentrations of nutrient elements with reference to the season and in respect to distance from shore expressed in p.p.m.

	Early Season	Late Season	On-Shore	Off-Shore
Ammonia	0.17	0.18	0.22	0.10
Total Nitrogen	0.44	0.37	0.41	0.35
Total Phosphorus	0.11	0.07	0.08	0.06
Soluble Phosphorus	0.05	0.03	0.04	0.03

From the results of another research project carried out by the Commission it was found that the average result of total phosphorus determinations from open water areas of Lake Ontario was 0.057 ppm as compared with the mean of the shore samples taken of 0.074 ppm. The mean of samples taken from the open water areas of Lake Erie was 0.073.

DISCUSSION

Algal Production

The most outstanding feature of the 1960 survey was the marked reduction in the growth of Cladophora, which was observed at all locations studied in both Lake Ontario and Lake Erie. In 1959 the first crop attained growths up to three feet and the second crop was approximately one foot in length. For the most

part the growth was deep green in color. In 1960 the free filamentous growth was never greater than approximately six inches in length and excepting for growths observed at the water-line on rocky outcrops, the alga appeared generally chlorotic.

For Lake Ontario, the very turbid condition of the water which prevailed throughout the season might be considered as a factor contributing to the reduced algal growth. In the Cladophora bearing areas in Lake Erie the water was very clear. The appearance and extent of the algal growth, however, was not unlike that in Lake Ontario.

As presented in Table I, records compiled for the Toronto area show that radiation was high both in 1959 and in 1960 in comparison to average values. In 1959, however, radiation was particularly high and associated air temperatures in 1959 exceeded those recorded during a similar period in 1960. These figures may be considered significant for the Bronte area and, inso-far as they reflect meteorological conditions which prevailed generally in southwestern Ontario, they may be applied, to some extent, to Lake Erie locations. Reduced radiation during the growing period, may have contributed to the generally reduced algal growth observed in both lakes in 1960.

TABLE IV

Average mean concentrations of nutrient elements contained in shore and lake samples taken in Lake Ontario in 1959 and 1960 expressed in ppm and compared with seasonal average concentrations recorded for Sturgeon Lake during 1952-55.

Element	1959	1960	Sturgeon Lake
Ammonia	*Shore - 0.06 Lake - 0.05	Shore - 0.22 Lake - 0.10	**Station #7-0.05 Station #3-0.65
Total Nitrogen	Shore - 0.94 Lake - 0.49	Shore - 0.41 Lake - 0.35	Station #7-2.12 Station #3-5.24
Total Phosphorus	Shore - 0.17 Lake - 0.06	Shore - 0.08 Lake - 0.06	Station #7-0.147 Station #3-0.966
Soluble Phosphorus	***Shore - 0.01 Lake - 0.01	Shore - 0.04 Lake - 0.03	Station #7-0.02 Station #3-0.59

* Shore Stations within 100 feet of Shore.

** Station #7 was representative of lake conditions and Station #3 represented the Scugog River 0.6 miles below a sewage out fall.

*** Based on 3 samples only.

As shown in Table IV, total nitrogen and total phosphorus concentrations at shore stations in Lake Ontario were approximately twice as great in 1959, when excessive Cladophora production occurred, as in 1960 when less algal production was observed. This reduction in concentrations may be related to the diluting effect of the much heavier rainfall which occurred in the Toronto area in 1960 (Table I). With respect to total phosphorus content, which is considered very significant with regard to the productivity

of lakes, concentrations in Lake Ontario 1959 approximated those recorded for Sturgeon Lake samples during the survey there. Under these conditions, both lakes were highly productive. Reduction in total phosphorus by one half in Lake Ontario in 1960 may be highly significant in explaining the sharp reduction in productivity. The similarity between total phosphorus concentrations determined in 1960 for shore stations in Lake Ontario and lake stations in Lake Erie, which represent the areas of Cladophora growth in the two lakes, adds emphasis to the importance of total phosphorus concentrations.

Laboratory experiments demonstrate the importance of nitrogen concentrations in determining algal growth and a reduction by one half in total nitrogen content in 1960 may be very significant, particularly at this level of concentration. In Sturgeon Lake, by comparison, total nitrogen concentration approximated 2.12 ppm (Table lV).

Ammonia and soluble phosphorus, which have not been considered directly indicative of lake productivity, were present in somewhat higher concentrations in 1960 than in 1959.

The figures recorded in Table IV for Station #3 are of interest for purposes of comparison. This station was known to be influenced by the effluent from a sewage disposal system.

On the basis of information provided by this survey, reduction in Cladophora production in Lake Ontario may be related to a reduction in radiation reaching the plants and to a reduction in fertility as indicated by smaller amounts of total nitrogen

and phosphorus in the lake water.

Algal Accumulations

Although the total production of Cladophora was much reduced in 1960, shore line accumulations were not eliminated. It has already been noted that the acreage involved in Cladophora production is very great in both Lake Ontario and in Lake Erie. Moreover, when the crop becomes free floating a large percentage of it may float freely and remain healthy for an extended period in free water. These masses may be carried for appreciable distances to accumulate on the shore when prevailing winds are suitable.

Even when growth is at a minimum, massive accumulations of algal material may occur. It is obvious that, to control the nuisance conditions related to Cladophora growth, the alga must be eliminated almost completely over large areas. Local control will be of no practical significance.

Mechanical Control of Nuisance Conditions

In some localities beach conditions may allow the consideration of various physical means of removal of the algal material. In other localities such methods would not be possible. At the best, this type of procedure is difficult and expensive, the masses involved may be large and, depending upon the wind direction, the material may accumulate more rapidly than it is removed.

The removal of obstructions at the water's edge, when

possible, may aid in preventing accumulations at a particular point and by allowing the area to be cleared by natural means if an accumulation has occurred.

Chemical Control of Cladophora

Growth conditions during the 1960 season were not conductive to the testing of algicidal chemicals. In general the alga appeared unhealthly and in Lake Ontario the turbidity of the water made the observation of growth and the evaluation of results of applications of chemicals difficult, and, at times, impossible.

No conclusive results were obtained with Aqualin in 1960. One series of applications, made in June in Lake Ontario, were subject to a great deal of dilution by diffusion and current action. Although eradication of the alga occurred in the vicinity, the plots were not clearly discernible and the very positive result, obtained in the same area in 1959, was not duplicated.

Later applications of Aqualin in Lake Erie were not effective. In one case, due to faulty calibration of the equipment, an ineffective concentration was applied. On another plot,6 ppm was applied but strong wave action occurred during and after the application and it is probable that the chemical was diluted below its effective concentration.

An application of TD-47 was applied on a similar location on an exposed, rocky reef in Lake Erie. At a concentration of 0.5 p.p.m. almost complete eradication of the alga was achieved. On the basis of one application only in a very exposed and difficult

location, this compound appears to be remarkably effective in the control of *Cladophora*. As in the case of Aqualin, however, TD-47 may be excluded from certain areas due to its toxicity to fish.

Applications of copper sulphate, sodium arsenite and Endothol were made without significant result. It was difficult to appreciate any result with Endothol. As in 1959, however, concentrations of 10.0 to 15.0 p.p.m. of copper sulphate and sodium arsenite did have a killing effect over a short period of time. The terminal portions of the filaments were killed on varying portions of the total stand. Eradication was not achieved, however, and after three to four weeks, the necrotic terminal growth sloughed off and the crop remained, apparently healthy, and only somewhat reduced.

On the basis of this study, the control of *Cladophora* is not to be anticipated by the application of even high concentrations (10.0 p.p.m.) of copper or arsenic compounds. Aqualin and TD-47, however, show promise.

Other Considerations Concerning Algal Control

Cladophora, as it occurs in Lake Ontario, presents a rather unique problem. It is practically a pure stand existing in almost total isolation so far as other obvious living organisms are concerned. More particularly, it occurs here in a very large body of water where, for testing purposes, it is impossible to control the dilution factors. If satisfactory progress is to be made in the assessment of various algicidal chemicals, more control must be obtained over the test plots. On the basis of

past experience, it will be difficult to find suitably confined areas which will be, at the same time, representative of lake conditions. The enclosing of plots with plastic sheeting is possible in small bodies but quite impractical so far as this lake is concerned. To minimize the dilution effect and to allow for valid interpretations of experiments, an effort must be made therefore, to apply tests over large areas.

In support of this point of view, it is pertinent to point out that, in other studies related to the control of rooted aquatics, when plots were treated in small bodies of water and when the test areas comprised a considerable percentage of the total area involved, satisfactory results were often obtained. Similar procedures, carried out in large bodies of water, failed to produce reliable results.

By virtue of its isolation, the control of Cladophora in Lake Ontario by chemical means may be possible and practical. In general, however, in an aquatic situation chemical control procedures may disrupt the ecology of the environment in such a way as to produce even greater problems. Chemical means of control quite possible, should be regarded as temporary expedients to be applied only until more natural means of control, based on the biological features of the organism concerned, are available.

Consequently, subsequent studies of the Cladophora problem must include controlled laboratory experiments designed to determine specifically the growth requirements of the alga and, possibly, to investigate the actual biological effectiveness of

various algicidal chemicals and other more natural means of control. In the field, intensive investigations of all pertinent physical and chemical environmental growth factors interpreted in the light of laboratory findings, are required. Testing of algicidal chemicals must be done on a scale large enough to yield reliable results.

APPENDIX

TABLE I

Concentrations of ammonia nitrogen in samples taken at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed in parts per million.

	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	0.26	0.05	0.30	0.09	0.21	0.28	0.26	0.18	0.22	1.85	0.21	0.30	0.05	0.22
Bronte West	0.35	0.40	0.40	0.21	0.09	0.15	0.49	0.38	0.11	2.58	0.29	0.49	0.09	0.35
" 100 ft	0.25	0.05	0.09	0.05	0.04	0.09	0.19	0.28	0.18	1.22	0.14	0.28	0.04	0.09
" 250 ft	0.21	0.05	0.21	0.05	0.05	0.05	0.49	0.09	0.06	1.26	0.14	0.49	0.05	0.06
" 500 ft	0.25	0.05	trace	0.07	0.18	0.18	0.26	0.09	0.09	1.17	0.13	0.26	0.0	0.09
" 1000 ft	0.35	0.05	0	0.34	0.05	0.07	0.39	0.28	0.15	1.68	0.19	0.39	0.0	0.15
" ½ mile	0.28	0.05	0.07	0.09	0.03	0.15	0.22	0.48	0.04	1.41	0.16	0.48	0.03	0.09
" 1 mile	0.21	0.05	0.39	0.04	0.13	0.07	0.06	0.38	0.31	1.64	0.18	0.39	0.04	0.13
TOTAL	2.16	0.75	1.46	0.94	0.78	1.04	2.36	2.16	1.16					
Average	0.27	0.09	0.18	0.12	0.09	0.13	0.29	0.27	0.14					

TABLE II

Concentrations of total (Kjeldahl) nitrogen in samples taken at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed in parts per million.

	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	0.70	0.50	0.39	0.32	0.29	0.48	0.29	0.50	0.43	3.90	0.43	0.70	0.29	0.43
Bronte West	0.70	0.70	0.45	0.32	0.29	0.48	0.49	0.68	0.30	4.41	0.49	0.70	0.29	0.48
" 100 ft	0.70	0.40	0.25	0.32	0.29	0.38	0.20	0.44	0.32	3.30	0.37	0.70	0.20	0.32
" 250 ft	0.21	0.40	0.48	0.18	0.40	0.40	0.53	0.31	0.22	3.13	0.35	0.53	0.18	0.40
" 500 ft	0.70	0.90	trace	0.32	0.28	0.28	0.73	0.31	0.31	3.83	0.43	0.90	trace	0.31
" 1000 ft	0.54	0.50	trace	0.51	0.15	0.28	0.75	0.31	0.22	3.26	0.36	0.75	trace	0.31
" ½ mile	0.38	0.40	0.20	0.32	0.15	0.28	0.73	0.55	0.16	3.17	0.35	0.73	0.15	0.32
" 1 mile	0.60	0.40	0.60	0.70	0.15	0.32	no sample	0.44	0.32	3.53	0.44	0.70	0.15	0.42
TOTAL	4.53	4.20	2.37	2.99	2.00	2.90	3.72	3.54	2.28					
Average	0.57	0.53	0.30	0.37	0.25	0.36	0.53	0.44	0.28					

TABLE III

Concentrations of total Phosphorus in samples taken at Lake Ontario stations in the vicinity of Bronte from June 9 to September 8, 1960, expressed in parts per million.

	June 9	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	0.105	0.095	0.075	0.063	0.045	0.060	0.350	0.032	0.065	0.040	0.930	0.093	0.350	0.032	0.064
Bronte West	0.128	0.075	0.110	0.051	0.035	0.044	0.195	0.096	0.077	0.02	0.831	0.083	0.195	0.02	0.076
" 100 ft	0.175	0.410	0.100	0.085	0.110	0.040	0.155	0.040	0.052	0.02	1.187	0.119	0.410	0.02	0.093
" 250 ft	0.047	0.105	0.076	0.036	0.045	0.047	0.185	0.054	0.035	0.02	0.650	0.065	0.185	0.02	0.047
" 500 ft	0.040	0.060	0.066	0.062	0.047	0.105	0.065	0.059	0.022	0.02	0.539	0.054	0.105	0.02	0.060
" 1000 ft	0.052	0.048	0.093	0.057	0.047	0.043	0.070	0.054	0.023	0.02	0.507	0.051	0.093	0.02	0.050
" ½ mile		0.120	0.046	0.070	0.050	0.045	0.095	0.054	0.028	0.02	0.528	0.059	0.120	0.02	0.050
" 1 mile		0.270	0.098	0.155	0.050	0.080	0.092	0.054	0.065	0.02	0.884	0.098	0.270	0.02	0.092
TOTAL	0.547	1.183	0.664	0.579	0.429	0.464	1.207	0.443	0.358	0.18					
Average	0.091	0.148	0.083	0.072	0.054	0.058	0.151	0.055	0.046	0.023					

TABLE IV

Concentrations of Soluble Phosphorus in samples taken at Lake Ontario stations in the vicinity of Bronte from June 9 to September 8, 1960, expressed in parts per million.

	June 9	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	0.034	0.036	0.055	0.049	0.028	0.043	0.073	0.014	0.015	0.02	0.367	0.037	0.073	0.014	0.035
Bronte West	0.046	0.036	0.023	0.051	0.030	0.020	0.040	0.034	0.022	0.02	0.322	0.032	0.051	0.020	0.032
" 100 ft	0.050	0.305	0.045	0.045	0.032	0.032	0.052	0.027	0.018	0.02	0.626	0.063	0.305	0.018	0.038
" 250 ft	0.033	0.027	0.030	0.040	0.031	0.031	0.048	0.022	0.024	0.02	0.306	0.031	0.048	0.020	0.031
" 500 ft	0.037	0.050	0.042	0.041	0.036	0.020	0.023	0.024	0.014	0.02	0.307	0.031	0.050	0.014	0.030
" 1000 ft	0.036	0.046	0.048	0.032	0.039	0.040	0.042	0.025	0.020	0.02	0.348	0.035	0.048	0.020	0.037
" ½ mile		0.050	0.030	0.050	0.037	0.030	0.057	0.018	0.024	0.02	0.316	0.035	0.057	0.018	0.030
" 1 mile		0.103	0.029	0.037	0.040	0.073	0.046	0.019	0.026	0.02	0.393	0.044	0.103	0.019	0.037
TOTAL	0.236	0.653	0.302	0.345	0.273	0.289	0.381	0.183	0.163	0.16					
Average	0.039	0.082	0.038	0.043	0.034	0.036	0.048	0.023	0.020	0.02					

TABLE V

Bacterial counts taken from samples obtained at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed as coliforms per 100 ml.

	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	274.		7.	100	1	6	13	76	48	525	65.6	274	1	30.5
Bronte West	169.		1.	2	0		54	30	1500	1756	250.8	1500	0	30
" 100 ft	3.		5	15	2	6	18	86	24400	24535	3066.8	24400	2	10.5
" 250 ft	6.		19	5	0	8	16	38	4600	4692	586.5	4600	0	12
" 500 ft	54.		200	0	0	5	11	28	13800	14098	1762.2	13800	0	19.5
" 1000 ft			9	1	0	38	21	47	1500	1616	230.8	1800	0	21
" ½ mile	3.		0	0	0	8	15	32	800	858	107.2	800	0	5.5
" 1 mile			0	0		3	19	45	1	68	11.3	48	0	2
TOTAL	509.		241.	123.	3	74	167.	382.	46649					
Average	84.8		30.1	15.4	0.4	10.6	20.9	47.8	5831.1					

TABLE VI

Concentrations of phenolic compounds in samples taken at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed in parts per billion.

	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	30.	0.	35.	9.	32.	6.	0.	0.	0.	112.0	12.4	35.0	0.0	6.0
Bronte West	8.	0.	15.	37.	0.	5.	0.	0.	0.	65.0	7.2	37.0	0.0	0.0
" 100 ft	70.	5.	4.	0.	6.	0.	0.	0.	0.	85.0	9.4	70.0	0.0	0.0
" 250 ft	12.	8.	12.	0.	3.	0.	40.	0.	0.	75.0	8.3	40.0	0.0	3.0
" 500 ft	25.	0.	7.	5.	18.	17.	0.	0.	0.	72.0	8.0	25.0	0.0	5.0
" 1000 ft	35.	0.	0.	12.	8.	3.	0.	0.	0.	58.0	6.4	35.0	0.0	0.0
" ½ mile	25.	10.	3.	3.	3.	6.	0.	25.	0.	75.0	8.3	25.0	0.0	3.0
" 1 mile	12.	3.	4.	0.	6.	23.	0.	20.	8.	76.0	8.4	23.0	0.0	6.0
TOTAL	217.	26.	80.	66.	76.	60.	40.	45.	8.					
Average	27.1	3.2	10.0	8.2	9.5	7.5	5.0	5.6	1.					

CLADOPHORA INVESTIGATIONS

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A Report of

OBSERVATIONS ON THE NATURE AND CONTROL OF
EXCESSIVE GROWTH OF CLADOPHORA SP. IN
LAKE ONTARIO AN D LAKE ERIE

B Y

DUNCAN A. MCLARTY

ACKNOWLEDGEMENTS

The Biology Branch of the Division of Laboratories was responsible for the organization and general direction of this project. Dr. Duncan A. McLarty of the Department of Botany, University of Western Ontario was employed by the Commission to undertake the study and was responsible for the field work and the preparation of this report.

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John H. Neil,
Supervisor, Biology Branch.

TABLE OF CONTENTS

OBSERVATIONS ON THE NATURE AND CONTROL OF EXCESSIVE GROWTH OF *CLADOPHORA* SP. IN LAKE ONTARIO AND LAKE ERIE

In the summers of 1957 and 1958 masses of *Cladophora* accumulated at various points along the northwesterly shore of Lake Ontario. The odour associated with the disintegration of this material constituted a serious problem for lake-shore property owners and, in November, 1958, a conference was called by the Ontario Water Resources Commission to consider the matter. As a result, investigations were planned and have been conducted in Lake Ontario and, to a lesser degree, Lake Erie during the summers of 1959, 1960 and 1961.

These investigations have included observations on the biology of the organism, chemical and physical environmental factors which might be associated with its growth and upon methods and materials for the chemical control or elimination of the alga. Although references to the nature and growth of *Cladophora* under certain conditions may be found in the literature, little or no information is available with respect to its growth and control in large bodies of water such as the Great Lakes.

The initial studies, as reported previously determined that the species with which we are concerned grows in water up to 10 feet in depth where a suitable substratum is provided for its attachment. Smooth areas of bed-rock are not usually involved but crevices in the rock and the protected edges of boulders, concrete or rock

that jetties and sea walls and other natural or artificial structures provide suitable conditions for attachment and growth. Areas having a cobble-stone bottom provide the most dense and uniform growths of Cladophora. Exposure to wave and other water action provides a necessary stimulus to growth.

The filamentous growth of the alga appears in the lakes toward the end of May. During June the growth is rapid and the lake bottom becomes covered by a growth of Cladophora which may be up to three or four feet in length with tangled plumes extending to the surface. When this "mature" condition is reached, usually by early July, the entire crop is capable of being removed by strong wave action. At this time, accumulations may occur. When the first crop is removed a second crop is already apparent. For the most part, however, this growth is minimal and has not been found to "mature" during the period of investigation.

On the basis of observations made in Lake Ontario and Lake Erie it is apparent that the alga is not influenced to any appreciable degree by water temperature and it has not been possible to interpret long range and seasonal fluctuations in growth with other chemical and physical lake properties which have been investigated.

All of the available chemicals for which algicidal properties have been claimed have been field tested during the initial studies. In general, copper and arsenic compounds, which are well known for their phytotoxic properties, have had no appreciable or significant influence on the alga under the conditions of testing. Aqualin, a solution of acrolein, and TD-47, an experimental derivative of 3,6-endoxo-hexahydrophthalic acid, however, produced some encouraging results.

The investigation was continued in 1961. Observations on the biology of Cladophora were continued but the primary purpose of the investigation was to select, if possible, an algicidal chemical which might be recommended by the Commission for use by municipalities or individuals for the control or elimination of Cladophora in Great Lakes locations.

THE BIOLOGICAL FEATURES OF CLADOPHORA

Seasonal Production

The genus *Cladophora*, according to some authors, includes approximately 160 species which are often not well defined. A great deal of taxonomic study will be required to provide for the certain recognition of species of the genus and, in the course of this investigation, attention has not been given to these problems.

The *Cladophora* species with which we are concerned is an attached, branched, filamentous green alga which may arise from a prostrate, rhizoidal, basal growth which may be perennial and from which regrowth may rapidly occur. Most commonly, in species of *Cladophora*, two plants which are morphologically identical in gross appearance occur in the life cycle. The diploid sporophyte plant produces haploid zoospores which, under suitable conditions, germinate to form gametophyte plants. These form motile gametes which, following sexual fusion, reproduce the sporophyte plant.

The sporangia and gametangia are produced continuously near the young tips of the filaments during the season. Consequently, motile reproductive bodies may be available at all times for the establishment of new growth. It should be noted, therefore, that the "mature" state of the alga does not relate primarily to a final fruiting period as is the case in higher plants. Rather it refers to a condition characterized by less healthy and vigorous growth and by physical weakening of the filaments so that they may be more easily broken free from their attachment.

In 1960 and 1961 *Cladophora* became apparent in Lake Ontario during the last week in May. At this time the initial, upright filaments consisted of only six or eight cells. The subsequent growth was rapid, however, and by mid-June the beds were covered by the lengthening filaments of the alga. By June 29, 1961, for example the filaments had attained a length of two to three feet and, in shallow areas, were emerging at the surface.

During late-June and throughout July there is a tendency for the alga to form rope-like, tangled plumes which extend greatly in length. In progressively deeper water these plumes reach the surface and the appearance of the lake and bathing conditions steadily deteriorate. At the same time the growth may appear slightly chlorotic. The formation of plumes is thought to involved the accumulation and tangling of free floating fragments rather than a marked elongation of individual filaments. In this condition, the crop is considered to be "mature" and shore accumulations may be anticipated if suitable lake conditions occur. In 1961, the plumed condition of the growth was attained by the end of June and the crop persisted until August 1, when an on-shore wind created waves of sufficient magnitude to break loose and remove the "mature" crop of Cladophora.

When the initial crop was removed the lake bottom was already covered by a second crop which was only a few inches in length. This crop persisted in a healthy but more restricted form throughout the balance of the season. During the periods of observations, which extended in some instances until October, the second crop was not found to "mature". It is obvious, however, that this crop does break away during the course of the winter because no Cladophora is apparent in the lake in early May.

During the growing season in 1961, sheets of asbestos and cement bricks were placed at various points in the lake to act as artificial substrata for the attachment of Cladophora. In every instance growths of the alga were obtained even in areas where, for the lack of suitable attachment, no growth was occurring normally. When sheets of asbestos were suspended near the surface of the water from buoys at distances up to two miles from shore, heavy growths of Cladophora developed. Spores are apparently present in the water at all times during the growing season and new growth may be established, consequently, at any time. Moreover, when satisfactory attachment at a suitable depth is provided, growths of Cladophora may occur

at off-shore locations in Lake Ontario as they have been observed on isolated, off-shore reefs in Lake Erie.

During the period of investigation the productivity of the alga varied significantly from season to season. In 1959 a moderately heavy growth occurred. In 1960 the crop was quite as extensive as in the previous year but a vigorous growth never developed while in 1961 the greatest productivity for the three year period was encountered.

Location and Extend of Cladophora Growths

In the areas studied in Lake Ontario and Lake Erie, *Cladophora* has been observed wherever a firm substratum is provided for its attachment and where the water is not greater than ten feet in depth approximately. Flat bedrock usually remains clear of growth during the early season. Growth, originating in the crevices, however, may cover the rock as the filaments extend in length later in the season. Rough, cobblestone deposits provide more satisfactory conditions for attachment and in such areas the densest growths will be encountered. Rock fill, piers and abutments serve also for the attachment of *Cladophora* and heavy growths are often found near the water line on such structures. Depending upon the slope of the bottom, algal beds may extend from the shore to points up to one thousand feet into the lake. While light may be a limiting factor in deep water, it is probable that physical factors related to water movement are of great importance with respect to the growth of the alga in such locations.

Although the growth of *Cladophora* is not continuous in all areas, due to depositions on sand and silt on the lake bottom, it is estimated that, in the Burlington-Port Credit area at least, thirty to fifty acres of the alga may be encountered for each linear mile of shoreline. Information received from other

sources indicates that the alga occurs commonly around the Lake Ontario shore from the Niagara River to beyond Oshawa.

So far as they have been observed in Lake Ontario the alga beds occur along the shore. In a similar fashion, in the Crystal Beach area of Lake Erie, rocky, algal infested outcrops occur from the water line out into the lake. In the vicinity of Port Colborne, bays occur which are devoid of Cladophora by virtue of deposits of sand and silt. The rocky points which delimit the bays bear algal beds for varying distances from shore. In the Lowbanks District, no such outcrops of rock occur at the shore but rocky reefs in the vicinity of Mohawk Island, two miles from shore, have been observed to be covered with a lush growth of algae. Under these conditions the algal accumulations along the mainland shore must have had their origin from the reefs several miles distant.

The Nature and Control of Shore-line Accumulations

To some extent the healthy, growing alga presents problems to swimmers, water skiers and operators of small boats and, as the crop "matures" and comes to the surface, the lake may become unsightly. The significant problem, however, is the accumulation and disintegration of large masses of free-floating algae along the shore.

It has been observed that the species with which we are dealing is stimulated in its growth by rough water action. Small fragments of the growth may be dislodged from time to time but a significant and complete removal of the standing crop does not occur until the "mature", plumed condition of the alga is attained.

Under these conditions, moderately heavy wave action will break loose not only the extended plumes but the dense bottom growth as well and a great tonnage of Cladophora will become free-floating. Large masses of this material may sink and accumulate on the lake bottom in deep water. Here the organic breakdown of the algal material may be accomplished without the creation of a problem. A large fraction of the dislodged algal material floats and may be carried out into the open lake by wind

and current action or may accumulate in varying amounts along suitably inclined shore-lines. Later, free floating material may be brought in from the open lake when suitable winds prevail. As a consequence, accumulations may occur over an extended period following the actual dislodgement of the crop and areas removed from beds of _Cladophora_ may suffer from the accumulation of these drifting masses of algal substance.

A prevailing on-shore wind may wash the alga on and around rock-filled shores, pile it to a depth of inches or several feet on the beach or compact it in the water in a band which may extend from a few inches up to 50 to 100 feet from shore. If the accumulation is allowed to dry it forms a very persistent, felt-like mass which is inoffensive. If it is subsequently soaked or if it has been constantly wet, the organic breakdown of the compacted mass will begin within a few days. The resultant black, oily mass involves a characteristic "pig pen odor" which may be detected up to a mile inland. Such massive accumulations may become dry and brown in colour on top and the nuisance condition may be temporarily removed. When disturbed the active breakdown process sets in again.

The mechanical removal and disposal of these accumulations has been undertaken by a number of private individuals. For a variety of reasons such procedures are somewhat impractical. Physical hazards along rocky shores are difficult to surmount with existing equipment and accumulations may occur repeatedly over a period of time to the end that the algal material is accumulating as rapidly as it is removed.

It has been observed that, by a shift in wind direction, accumulations may be dispersed naturally. Local currents created by vigorous pumping may be used to remove local accumulations and, on occasion, the removal of weirs and other such obstructions may influence the incidence of accumulations at selected locations.

In our present state of knowledge the control of accumulations of _Cladophora_ may best be achieved by controlling or preventing the growth of the alga by chemical or other means. This achievement will require the application of control procedures along many miles of shore and over a large number of acres of algal beds. By virtue of the nature of the accumulations and the conditions associated with their occurrence, local treatment will provide no assurance of protection from accumulations in any selected community.

CHEMICAL ANALYSIS OF LAKE WATER

Water currents in the shoreline areas producing Cladophora are known to move along the shore in response to winds. The direction and speed of the current is a reflection of the direction, strength and duration of the wind. It was believed that nutrients from various sources such as river water and waste sewers would not be immediately diluted in the main body of Lake Ontario but would be carried over the growth areas by currents moving along the shore. Thus while the fertility of the main body of the lake might not be rich enough to support the algae growth, sufficient nutrients were trapped within the shoreline currents to develop nuisance quantities of the algae. In order to determine the validity of this assumption chemical analyses have been carried out over a three year period on one range of samples taken from the shore to one mile into the lake within the area affected by the algae. The data for 1961 are included in the appendix and a summary of the results for three years appear in Table I. It will be noted from this table that in ten of the twelve means reported the concentration in the shore samples was equal to or greater than in the lake. There is reason to believe that the samples indicated as lake taken 0.5 and 1.0 miles offshore are still influenced by the shoreline discharges and are not truly indicative of the main body of Lake Ontario.

Results of chemical analyses for Sturgeon Lake have been included for comparison. The chemical constituents of this lake are indicative of water naturally rich in nutrients and one which supports nuisance growth of blue green algae. The total organic content of this water as indicated by the total nitrogen and total phosphorous levels exceed Lake Ontario by a factor of five and two respectively. The average concentrations of ammonia and soluble phosphorous are of the same order. As these are nutrients sought after by the plants it is apparent that in both cases

TABLE I

Average concentrations of nutrient elements in samples taken in Lake Ontario during 1959-61 along with average concentrations recorded for Sturgeon Lake during 1952-55 in parts per million

Element		1959	1960	1961	Sturgeon Lake and Saucog River
Ammonia	Shore -	0.06	0.16	0.18	Station #7 - 0.05
	Lake -	0.05	0.11	0.19	
Total Nitrogen	Shore -	0.62	0.38	0.36	Station #7 - 2.12
	Lake -	0.47	0.37	0.35	
Total Phosphorous	Shore -	0.09	0.06	0.07	Station #7 - 0.15
	Lake -	0.06	0.07	0.04	
Soluble Phosphorous	Shore -	0.01	0.04	0.02	Station #7 - 0.02
	Lake -	0.01	0.03	0.01	

they are reduced to comparable levels. These comparative figures indicate that Lake Ontario water is much lower in the general level of fertility than many of our inland waters but because of the favourable environment offered for the growth of this species, together with a small increase in fertility, Cladophora is able to develop in quantity.

The relationship between the development of Cladophora growths of nuisance proportions and a definative source of nutrients is illustrated in several specific instances. The Watcher Islands in Georgian Bay are a series of rocky reefs located in a remote area far from any human influence. They are, however, heavily utilized for nesting purposes by gulls and terns and in this way received considerable fertilization. Cladophora grows luxuriently around these islands but is not found on similar shores in the vicinity. Two municipalities on Lake Huron discharge their

municipal wastes at the waters edge in a rocky shoreline area. In both cases, nuisance growths of Cladophora develop where as little or no growth can be found in similar areas not influenced by the sewage. A further instance has been noted on the St. Lawrence River where an industrial discharge containing a nitrogenous waste enters the river at the shoreline. An abrupt growth of Cladophora develops at this point and continues downstream for about half a mile.

The average concentrations of nitrogen and phosphorous as indicated in Table I do not appear to bear a specific relationship to the quantity of algae produced. In the years 1959 and 1961 luxurient crops were produced while 1960 was relatively poor. These figures do indicate the relatively low levels of nutrient substances which will promote the growth of nuisance quantities of this alga.

Meteorological Conditions

The meteorological records for Toronto presented in Table II are considered as representing the Oakville area, (distance 20 miles). The mean air temperatures, were less than normal and less than those recorded for May and June in 1960. During July and August, 1961, air temperatures were similar to those in 1960 and close to normal while in September warmer than normal weather prevailed. The water temperatures indicated were recorded from the intake water at the Oakville water treatment plant. The intake draws water from a depth of twenty five feet so that the temperatures are likely to be a few degrees colder than the 0' to 10' area where most of the growth takes place. Wide variations in temperature may occur very rapidly with the mixing of profundal waters. Temperature changes of as much as twenty degrees have been noted in a short interval.

Bright sunshine hours and total radiation were uniformally less in 1961 than in 1960 and less than the recorded normal figures for June, July and August. May and September were generally brighter.

The rainfall was greater than average in 1961 and with the exception of May, total precipitation was greater in 1961 than in 1960.

In general, the records in Table II indicate lower temperatures and lower radiation and total sunshine in the growing period of 1961 than for similar periods in 1960. No co-relation is apparent on the basis of these figures to explain the fact that growth of *Cladophora* was restricted in 1960 and heavy in 1961. In a similar fashion, it is difficult to demonstrate any direct relationships between the rainfall recorded for the three years in question, the nutrient content of the lake water (Table I) and the algal productivity.

TABLE II

Meteorological Data as Recorded for Toronto

		May	June	July	Aug.	Sept.
Mean Air Temperature						
°F	1959	58	68	73	74	66
	1960	56	65	69	69	65
	1961	53	63	71	69	68
	Normal	59	66	71	70	62
Total Precipitation						
	1959	1.19	1.14	1.23	1.35	3.79
	1960	5.29	2.43	4.38	1.23	0.31
	1961	2.80	4.31	4.40	1.98	1.50
	Normal	2.76	2.49	3.23	2.39	2.56
Bright Sunshine Hours						
	1959	247.8	252.9	298.1	251.3	222.4
	1960	144.0	265.1	307.1	291.2	181.1
	1961	236.1	235.2	260.7	237.8	223.4
	Normal	220.1	256.8	289.4	258.5	198.0
Radiation B.T.U./ft^2						
	1959	58287	61510	66037	53808	41605
	1960	44007	60771	52871	57312	38979
	1961	53674	54369	57526	50831	41784
	Normal	51652	57949	60040	51097	38127
Mean Water Temperature(F)*			June 15-30	July	Aug.	Sept. 1-15
	1959		46.1	52.2	57.7	60.1
	1960		54.5	51.5	63.9	68.2
	1961		44.8	50.4	58.6	60.1

*Recorded at Oakville Water Treatment Plant Depth 25'

CLADOPHORA CONTROL BY CHEMICAL MEANS

Testing of Algicidal Chemicals in Polyethylene Bags

To determine the relative effectiveness of various algicidal chemicals some preliminary experiments were done using polyethylene bags with a capacity of five gallons. Solutions of the chemicals were placed in the bags and excised portions of *Cladophora* were added. To assure temperature and lighting factors which would be representative of those prevailing in the lake the bags were attached to a frame and suspended in the lake at the Bronte pier.

The results of these tests are recorded in Table III

TABLE III

Chemical	Concentration in ppm	Observation
TD-47	0.5	Young cells bleached and disrupted. Old cells green and healthy.
	0.3	Young cells bleached and disrupted. Old cells green but plasmolysed.
	0.5	Young cells bleached and empty. Old cells disrupted, plasmolysed and bleached.
	3.0	All cells completely disrupted and dead.
TD-191	0.3	Young cells bleached. Older cells green but plasmolysed.
Aqualin	0.5	Sample normal green colour but young cells severly plasmolysed. Old cells slightly plasmolysed.
	1.0	As above but more seriously plasmolysed,
	2.5	Quite as green as the check but all cells completely plasmolysed.
	10.0	Green in colour but all cells severely plasmolysed and the contents disrupted and irregularly condensed.
Diquat	3.0	Green in colour. All cells plasmolysed without disruption. As above
	6.0	As above.
Paraquat	2.0	Green in colour but plasmolysed more strongly than in Diquat
	4.0	Green in colour. Severe plasmolysis.
Check	---	Green, healthy and fruiting.

When these tests were terminated and observations made at the end of twenty four hours exposure it was found that all of the algicides tested produced a killing effect at all concentrations used. In the case of TD-47, 0.1 p.p.m. killed only the terminal, young cells while at 0.3 p.p.m. and above the old cells as well as the young cells were killed. With both TD-47 and TD-191 the Cladophora was bleached and the contents of the cells were completely disrupted in the young cells particularly. Later, in lake tests, the bleaching of the alga was noted in as short a period of time as five minutes.

With Aqualin, similar results were obtained at slightly higher concentrations. At 0.5 p.p.m. old as well as young cells were affected. In the case of this product the colour of the gross sample was not altered during the period of the test and the alga did not dissociate within the twenty four hour period of observation.

At the concentrations used both Diquat and Paraquat killed all of the cells present without destroying the chlorophyll and bleaching the specimen.

From these tests it may be concluded that all of the chemicals concerned are toxic to Cladophora. It can not be assumed, however, that similar results may be obtained at similar concentrations when applications are made to algal plots under natural conditions. In nature the chemical properties of the water and the presence of other living organisms may have a profound influence upon the activity of the algicidal chemical. More particularly, the problem of maintaining a killing concentration in the vicinity of the algal growth for a sufficiently long period of time is critical in the case of practical control procedures while it is not involved in laboratory tests such as those reported here.

Field Testing of Algicidal Chemicals

Algicidal chemicals were tested on one acre test plots which were measured and marked with anchored buoys in selected areas where heavy and uniform growths of Cladophora were established. To facilitate the making of observations and to conserve experimental material, plots were selected on which the water did not exceed 6 feet in depth. In all cases, similar adjacent areas were observed, assessed and reserved for use as check plots.

For these applications an aluminum 16 foot boat, powered by an 18 horse power motor, was used. This craft was large enough to accomodate the equipment required but had a shallow enough draft to permit its use in the more shallow areas of the plots.

Liquid preparations were applied using a gasoline powered centrifugal pump which was fitted with a duel intake. By this means it was possible to admit to the suction side of the pump algicides in actual measured amounts or at a fixed rate as determined by a flow meter. In the pump the chemical to be applied was diluted in a large volume of water pumped from the lake. A 12 foot boom, from which four drop nozzles were suspended below the level of the surface of the lake, was attached to the stern of the boat. By this means chemicals were applied in a 16 foot swath and at a reasonable depth to bring the chemical more nearly in direct contact with the algal growth.

Crystalline and granular preparations were applied using a common cyclone seeder. Relatively coarse crystals and granules were selected to assure satisfactory distribution and to provide for a rapid settling of the chemical. By this means it was anticipated that the greatest concentration of the chemical would be attained at or near the bottom of the lake in direct contact with the algal growth.

In all cases the rates of application were calculated on the basis of the total volume of water on the plot.

Test applications were made during periods of calm and, if possible, when it was anticipated that calm conditions might prevail long enough to provide satisfactory contact with the alga. At the time of application, dye bags were anchored at a position about twelve inches above the bottom of the lake in the plot. By this means the direction and rate of drift was obtained.

A satisfactory result may be anticipated only when a killing concentration of the algicidal chemical is maintained in the vicinity of the algal growth for a sufficiently long period of time. Certain precautions must be taken, therefore, when tests are done on relatively small plots in large bodies of water. To overcome the dilution of the chemical by diffusion and by water action, higher concentrations must be used and, when practical, larger test plots treated. Commonly, when a relatively large portion of the total area is treated, the results are more satisfactory and reliable.

Accordingly, in the course of the investigations, six 6 acre plots were treated with granular and crystalline preparations. These applications were made by a commercial crop dusting aircraft.

In 1959 three 1 acre plots were treated with 3.0, 6.0 and 10.0 p.p.m. respectively of aqualin. At the two lower rates moderate and severe removal and inhibition of the crop was achieved. At 10.0 p.p.m. the crop was completely removed. The water temperature was 15°C. In 1960 similar applications were made to three 1 acre plots when the water temperature was 14°C. A storm followed immediately after the treatments were applied and removed the markers. There was evidence of a good deal of killing in the vicinity of the plots but a proper assessment of the results was not possible. Two applications were made later in 1960 at Mohawk Island in Lake Erie at the rate of 2.0 and 6.0 p.p.m. with the water temperature at 22°C. Rough water

conditions occurred during the period of application and it is probable that the rates of application were not high enough for the prevailing conditions. No appreciable control was achieved.

At the same location in 1960, near Mohawk Island, one application of 0.5 p.p.m. of TD-47 was made in water which was 21°C. Despite relatively rough water conditions which prevailed during the period of application, approximately 90% of the crop was removed by the treatment.

As has been previously reported, copper and arsenic compounds, which were tested during 1959 and 1960, had no appreciable effect. In view of reports of satisfactory control of Cladophora in smaller bodies of water, and even in the Great Lakes, by copper sulphate, it was concluded that more exhaustive tests should be made of this compound in 1961. Aqualin and TD-47, both of which had shown promise in the initial tests, were selected as well for further study. The results of applications of algicidal chemicals made in 1961 are summarized in Table X.

Plots 1 to 4 and plots 11 and 12 were six acres each. The granular and crystalline preparations were applied from a crop dusting aircraft. All other plots were one acre in size and were treated from the boat.

TABLE X

Summary of results of applications of algicidal chemicals for the control of *Cladophora* 1961

Date of Application	Test Plot Number	Location	Algicide Applied	Concentration (ppm)	Result
June 29	1	L. Ontario	TD-47G	0.25	Complete kill of bottom growth. Plumes persisting. Partial removal.
	2	L. Ontario	TD-47G	0.5	Similar to above with more killing of plumes and with more crop removal
	3	L. Ontario	$CuSO_4$	10.0	Initial chlorosis in some areas. Otherwise no result
	4	L. Ontario	$CuSO_4$	5.0	No result
July 5	5	L. Ontario	TD-191	0.5	Bottom growth killed with some plumes removed. Some areas cleared but mostly persisting
July 6	6	L. Ontario	Aqualin	5.0	No result
	7	L. Ontario	Aqualin	6.0	Crop killed and removed
	8	L. Ontario	TD-47L	0.5	Complete kill of crop but with no removal
July 26	9	L. Erie	Aqualin	3.0	75% crop removal
	10	L. Erie	Aqualin	6.0	90% crop removal
Aug. 15	11	L. Ontario	TD-47G	0.5	Chlorosis of crop with a partial removal of the crop
	12	L. Ontario	TD-47G	0.25	Chlorosis of crop with removal leaving only a "stubble" growth over area
Aug. 23	13	L. Erie	TD-47G	0.25	Chlorosis and almost complete removal of crop
	14	L. Erie	TD-47G	0.5	Chlorosis complete and partial removal of crop

G — granular preparation
L — liquid preparation

Aerial applications of copper sulphate ($CuSO_4.5H_2O$), made on six acre plots at rates of 5.0 and 10.0 p.p.m., produced no visible result at the lower rate of application. At 10.0 p.p.m. some chlorosis of the terminal filaments was apparent initially but the treatment had no permanent influence upon the growth. After a period of two weeks there was no observable difference between the check plots and those to which copper sulphate had been applied. As a result of these large scale applications

and in view of previous testing of copper sulphate on one acre plots it, is concluded that this compound is unsuitable for the control of Cladophora in large bodies of water.

Aerial applications of granular TD-47 (Plots 1 and 2) were made when the water temperature was 8°C. and at a time when the crop was attaining its plumed, "mature" condition. In each case all of the bottom growth was bleached and killed but not removed. At 0.5 p.p.m. a greater killing of the plumes was achieved than with 0.25 p.p.m. It is believed that the hard-baked granules sank rapidly to the bottom and released most of the chemical at that point without establishing a killing concentration at higher levels in the water. In contrast to the result obtained with TD-47 in 1960 when the crop was destroyed and removed, the bleached remains of this crop persisted on the plots for 4 weeks until removed by a storm on August 1, 1961. The initiation of the second crop on the plots was not inhibited by the treatment.

Aerial applications (plots 11 and 12) were made in Lake Ontario when the water temperature was 16°C. and after the establishment of the second crop. In general the results were more marked than in the case of earlier applications made in colder water. In each case the crop was bleached and partially removed but the removal was much more marked in the plot treated at the rate of 0.25 p.p.m. than in the plot to which 0.5 p.p.m. was applied.

Applications of TD-47 (Plots 13 and 14) which were made in Lake Erie when the water temperature was 22°C. produced much more satisfactory results. In each case the Cladophora was almost completely killed and removed leaving cleared areas in the plots. As described above for plots 11 and 12, the crop appeared to be more effectively removed by treatment with 0.25 p.p.m. than with 0.5 p.p.m.

One application of a liquid formulation of TD-47 was made (Plot 8) in Lake Ontario at the rate of 0.5 p.p.m. The result was somewhat more satisfactory than that obtained with a similar application of a granular preparation. The entire crop

was killed at all levels in the water but the bleached filaments were not removed.

During 1961, the very satisfactory control of *Cladophora*, which was achieved with TD-47 in 1960, was never duplicated, even under apparently similar conditions, and it is probable that ecological factors not yet been taken into consideration, are responsible for the variable results obtained.

On the basis of these tests it is apparent that the effectiveness of TD-47 in the control of *Cladophora* is much reduced when the water temperature is below approximately 15°C. The action of the chemical is rapid, however, and the retention time may be reduced to a matter of minutes. It is suggested that, with improved timing and methods of application, suitable control of *Cladophora* may be achieved ultimately by the use of this chemical.

Aqualin was applied at rates of 3.0 and 6.0 p.p.m. in Lake Ontario (Plots 6 and 7) and in Lake Erie (Plots 9 and 10). The former tests were conducted when the water temperature was 10°C. and no result was obtained with 3.0 p.p.m. At the rate of 6.0 p.p.m., however, Aqualin killed and destroyed the crop over the entire plot. In Lake Erie, with the water temperature at 21°C., 75% and 90% of the crop was removed in the 3.0 and 6.0 p.p.m. plots respectively. Moreover, as a result of drift, extensive areas outside the plots were killed in each case.

For the satisfactory application of Aqualin, it has been recommended that the water temperature should be greater than approximately 20°C. These results support this contention. With suitable water temperature conditions and when the period of retention is adequate, positive control of Cladophora may be achieved with concentrations as low as 3.0 p.p.m.

DISCUSSION

For the most part, healthy, attached growths of Cladophora do not create serious problems although, in terminal stages of development, the alga may reach the surface to interfere with boating and to present an unsightly appearance. When the alga becomes free-floating, however, and large masses accumulate and disintegrate at various points along the shore major problems result. The odour is most offensive and the disintegrating material itself makes the beaches and the lake front quite unsuitable for use. The combined detrimental effects constitute a serious and complex situation. The size of the lake itself, the extend of the algal beds and the need for information concerning the growth and control of such aquatic organisms combine to make progress toward a solution of the problem both slow and difficult.

The most direct approach to a solution might involve mechanical removal of the accumulated masses. This procedure has been applied by a number of individuals and municipalities on suitable shorelines and where the rock formations do not preclude the use of mechanical equipment, satisfactory results may be obtained. Unfortunately, however, this material normally lodges in rough and unaccessible areas which cannot be worked with the available mechanical devises.

There have been reports of efforts designed to control the odour which results from the organic breakdown of the algal masses and some chemicals have been recommended for such use. In the case of minor accumulations and for short periods of time it is conceivable that some temporary relief might be afforded by this means. If the odour is to be actually prevented, however, the entire mass of algal material would require to be sterilized and to be kept steril continuously. Biologically, this is not feasible.

In our present state of knowledge the control of Cladophora nuisances involve the control of growth of the alga directly on the beds or the physical removal of shoreline accumulations. Cladophora growths develop profusely to depths of ten feet and it has been estimated that thirty to fifty acres of the growth may be present along each linear mile of shore in the affected areas of Lake Ontario. The algal growth may cover the lake bottom completely and the filaments may become three to four feet in length. Since the ultimate accumulation of this material at the shore involved the breakoff of the crop and its transport by wind and current action it will be necessary to apply control measures over large areas to provide any assurance of protection against accumulations in any one specific area. Moreover, since it is an accumulation problem, complete control will be required. It has been noted that, even when the algal crop is minimal, it is possible to have very heavy localized accumulations. Conversely, a heavy crop of alga does not necessarily mean that heavy accumulations will occur, as this will depend upon wind and current action.

Excessive growths of aquatic plants may well be associated with high levels of concentration of nutrient salts present in the water. The ultimate control of nuisance aquatic growths may involve widespread efforts to prevent the rapid mineralization of natural waters which is going on today in most populated and developed communities. Before such procedures may be even contemplated, however, intimate knowledge of the nutritional requirements of the various plants concerned must be acquired and information concerning the extent to which nutrients in natural waters might be reduced must be obtained.

With respect to Cladophora, levels of concentration of nitrogen and phosphorus have been determined for Lake Ontario during the period of investigation. In terms of total nitrogen and total phosphorous determinations, the highest concentrations were recorded in 1959 and the lowest in 1961. No direct co-relations have been made between levels of nutrient concentrations and Cladophora production, but it

is obvious that they have not been limiting values. During the period of investigation, the heaviest crop occurred in 1961.

The influence of specific nutrients such as those associated with organic wastes, the effect of water movement upon the utilization of available nutrients and other problems must be investigated with _Cladophora_ under controlled conditions to provide for a complete understanding of [illegible]. This basic and ultimate means of control, based upon nutritional factors, is not feasible now but should not be neglected.

For the control of _Cladophora_ in the Great Lakes, the application of algicidal chemicals holds the greatest immediate promise. A suitable algicide must be toxic enough to kill the nuisance growth but not so toxic to other living organisms as to create problems. Its stability and its rate of absorption and action must be such as to make possible an adequate retention time and killing action. With respect to Lake Ontario, a chemical which would be effective at low temperatures would be desired. Physical and chemical properties which enable the compound to be economically and effectively applied are essential in addition to low initial cost.

Aqualin and TD-47, among all the algicides tested, have been found the most promising chemicals for _Cladophora_ growths. At 3.0 p.p.m. to 6.0 p.p.m. of Aqualin satisfactory results may be obtained in water 20.0°C or higher. With TD-47 0.25 to 0.5 p.p.m. applications have given similarly satisfactory results in water 15.0°C. or warmer. These results are not thoroughly reproducable for reasons which are unknown at the moment. Similar applications made under apparently similar conditions have given results ranging from complete control to no control despite the fact that, from laboratory tests, the phytotoxic properties of these compounds is unquestioned. Some factor in the environment, which has not been recognized and taken into consideration, is involved.

The continued study of the application of both of these compounds with respect to their formulation, methods of application and to the influence of chemical, physical and biological factors in the lake upon their activity, is warranted.

With respect to general toxicity, each of these compounds is toxic to fish and other life at levels well below the concentrations required for satisfactory algicidal action. In this problem, however, an almost pure stand of Cladophora is involved and as fish are not numerous in Lake Ontario in the areas where treatment will be required it may be possible to use these compounds.

Considering Aqualin and TD-47 from the standpoint of cost, rough estimates only are available since Canadian prices have not yet been firmly established. Treatment with Aqualin, at the rate of 3.0 p.p.m. and 6.0 p.p.m. on a four foot acre, is estimated to cost between $23.00 and $46.00 for materials.

It is estimated that the cost of material for applications of 0.25 and 0.5 p.p.m. of TD-47 to a four foot acre would be $18,00 and $36.00 respectively.

The cost of application for granular material applied by air will be approximately $4.00 per acre TD-47 may be prepared as granular material so that the estimated cost of this material applied would be $40.00 per acre. Aqualin can only be applied under water so that any treatment using this chemical must be done by boat. The cost of this operation is likely to be greater than air application so that something in excess of $50.00 per acre would be anticipated.

Basted on a figure of 30 acres of algal beds per linear mile of shore and a mean depth of four feet the materials and application cost for treatment with TD-47 at the higher rate would be $1200 per mile of frontage and $1500 per mile for Aqualin.

SUMMARY

1. *Cladophora* grows in nuisance quantities in extensive areas of the Canadian waters of Lake Ontario and Lake Erie where suitable bottom and water movement are present. Isolated occurrences in Lake Huron, Georgian Bay and the St. Lawrence River are reported.
2. Reproductive bodies are formed continually throughout the growing season and whenever suitable conditions are provided growth may be rapidly established.
3. Growth commences late in May and the crop "matures" in July. When "mature" the crop may be broken loose by wave action and free-floating masses of algal material may subsequently accumulate and disintegrate along the shore. A second crop, which develops as the first crop breaks loose, has not been observed to break off and cause accumulations to the same extent.
4. *Cladophora* tolerates a wide range of water temperatures. Meteorological factors factors and concentrations of nutrient elements, insofar as they have been studied during this investigation, have offered no basis for an explanation of seasonal fluctuations in algal productivity.
5. Nuisance quantities of *Cladophora* appear to develop in response to fertility where other environmental conditions are suitable. In the Great Lakes a small increase in nutrient concentration is sufficient to promote the growth of this alga. An exception to this may be Lake Erie where the general level of nutrients may be sufficient to permit Cladophora growths. In a number of instances the growth of the alga can be specifically related to a single nutrient source.

6. Copper sulphate has been shown to be ineffective in the control of *Cladophora* under lake conditions. Aqualin and TD-47 have been shown to be capable of controlling the growth of the alga at reasonable levels of concentration. The results, however, are not reliable and capable of duplication. More developmental work is required to determine the factor or factors which is responsible for the variability of the results.

RECOMMENDATIONS

1. In view of the success already attained in the control of *Cladophora* by applications of Aqualin and TD-47, inv[illegible]tions of these compounds should be continued. Studies should involve types of formulations and methods of application and should be designed to determine the factor or factors in the lake environment upon which the variability in the effectiveness of these chemicals depends.
2. New compounds and new formulations, as they are made available by industry, should be tested and evaluated with respect to this pressing problem which is serious now and which is likely to become more serious in the future.
3. To derive practical and true evaluations of algicidal preparations, large scale applications must be made.
4. Limnological studies with respect to the proper locations for sewage and industrial waste outfalls, which might help to minimize the problem of *Cladophora* production, are recommended.
5. Intensive studies under laboratory conditions, concerning the biology of *Cladophora* should be supported and promoted.

LAKE ONTARIO – LAKEFRONT SURVEY

1961

PHOSPHATES (PPM)
- TOTAL (T)
- SOLUBLE (S)

RANGES

DATES	100'		250'		500'		LO 54.7 1000'		½ MILE		1 MILE		AVG		LO 54.1 BRONTE EAST		LO 51.9– 51.6 BRONTE WEST	
	(S)	(T)	(S)	(T)	(S)	(T)	(S)	(T)	(S)	(T)	(S)	(T)	(S)	(T)	(S)	(T)	(S)	(T)
JUNE 7	0.01	0.06	0.00	0.04	0.00	0.05	0.00	0.04	0.00	0.03	0.00	0.02	0.00	0.04	0.02	0.06	0.01	0.60
13	0.02	0.06	0.04	0.04	0.02	0.03	0.00	0.05	0.00	0.06	0.00	0.03	0.01	0.05	0.01	0.05	0.01	0.05
21	0.03	0.08	0.01	0.06	<0.01	0.05	0.02	0.07	0.01	0.03	<0.01	0.04	0.01	0.06	0.01	0.04	0.01	0.06
28	0.02	0.03	0.02	0.04	0.02	0.03	0.02	0.03	0.02	0.04	0.02	0.03	0.02	0.03	0.02	0.05	0.02	0.04
JULY 11	0.01	0.05	0.02	0.05	0.02	0.06	0.02	0.06	0.02	0.05	0.02	0.05	0.02	0.05	0.01	0.06	0.01	0.05
19	0.01	0.09	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.06	0.00	0.05	0.00	0.07	0.01	0.06	0.00	0.01
27	0.01	0.07	0.01	0.07	0.00	0.05	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.05	0.00	0.08	0.01	0.08
AUG. 9	0.03	0.06	0.02	0.06	0.02	0.05	0.00	0.05	0.00	0.03	0.00	0.03	0.01	0.05	0.00	0.04	0.04	0.07
17	0.09	0.14	0.02	0.05	0.01	0.04	0.00	0.03	0.01	0.06	0.00	0.04	0.02	0.06	0.09	0.15	0.04	0.09
22	0.08	0.15	0.18	0.22	0.03	0.06	0.04	0.07	0.01	0.05	0.03	0.07	0.06	0.10	0.05	0.11	0.08	0.20
29	0.03	0.17	0.04	0.11	0.04	0.10	0.03	0.07	–	–	0.03	0.05	0.03	0.10	0.03	0.07	0.03	0.06
SEPT. 6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.01	0.06	–	–
12	0.00	0.01	0.00	0.04	0.00	0.05	0.00	0.04	0.01	0.06	0.00	0.04	0.00	0.04	0.04	0.09	0.00	0.06
AVERAGE	0.03	0.08	0.03	0.07	0.01	0.05	0.01	0.05	0.01	0.05	0.01	0.04	0.02	0.06	0.02	0.07	0.02	0.11
MAXIMUM	0.09	0.17	0.18	0.22	0.04	0.10	0.04	0.07	0.02	0.06	0.03	0.07			0.09	0.15	0.08	0.60
MINIMUM	0.00	0.01	0.00	0.04	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.02			0.00	0.04	0.00	0.01
MEDIAN	0.02	0.07	0.02	0.06	0.02	0.05	0.00	0.05	0.01	0.05	0.00	0.04			0.01	0.06	0.01	0.06

139

LAKE ONTARIO – LAKEFRONT SURVEY

1961

NITROGEN AS N (PPM)

- FREE AMMONIA (FA)
- TOTAL KJELDAHL NITROGEN (K)

RANGES

DATES	100'		250'		500'		L054.7 1000'		½ MILE		1 MILE		AVG.		L054.1 BRONTE EAST		L051.9– 51.6 BRONTE WEST	
	(FA)	(K)	(FA)	(K)	(FA)	(K)	(FA)	(K)	(FA)	(K)	(FA)	(K)	(FA)	(K)	(FA)	(K)	(FA)	(K)
JUNE 7	0.32	0.62	0.48	0.49	0.28	0.66	0.06	0.23	0.32	0.33	0.36	0.36	0.30	0.45	0.13	0.42	0.13	0.42
13	0.30	0.53	0.26	0.30	0.53	0.86	0.06	0.43	0.22	0.53	0.18	0.30	0.26	0.49	0.22	0.40	TRACES	0.23
21	0.20	0.43	0.12	0.66	0.08	0.16	0.12	0.33	0.08	0.26	0.18	0.39	0.13	0.37	0.12	0.23	0.20	0.26
28	0.26	0.30	0.18	0.20	0.20	0.23	0.10	0.13	0.14	0.20	0.36	0.36	0.21	0.24	0.18	0.18	0.08	0.13
JULY 11	0.20	0.26	0.38	0.46	0.23	0.26	0.20	0.20	0.15	0.30	0.29	0.30	0.24	0.30	0.08	0.20	0.13	0.20
19	0.28	0.40	0.49	0.92	0.28	0.94	0.13	0.26	0.13	0.46	0.26	0.75	0.26	0.62	0.13	0.23	0.03	0.33
27	0.30	0.33	0.21	0.76	0.28	0.33	0.10	0.13	0.26	0.26	0.13	0.17	0.21	0.33	0.16	0.30	0.15	0.20
AUG. 9	0.19	0.33	0.36	0.40	0.36	0.40	0.22	0.26	0.12	0.26	0.38	0.40	0.27	0.34	0.19	0.33	0.13	0.20
17	0.10	0.13	0.11	0.20	0.10	0.13	0.10	0.13	0.11	0.26	0.09	0.13	0.10	0.16	0.09	0.20	0.11	0.26
22	0.13	0.26	0.10	0.17	0.20	0.20	0.11	0.13	0.16	0.20	0.16	0.20	0.14	0.19	0.13	0.30	0.13	0.30
29	0.05	0.46	0.05	0.46	0.06	0.40	0.11	0.33	0.08	0.40	0.05	0.40	0.07	0.41	0.11	0.79	0.12	0.40
SEPT. 6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.21	0.46	–	–
12	0.39	0.53	0.07	0.70	0.10	0.92	0.20	0.36	TRACES	0.53	0.21	0.66	0.16	0.62	0.08	0.20	0.08	0.30
AVERAGE	0.23	0.38	0.23	0.48	0.23	0.46	0.13	.24	0.16	0.33	0.22	0.37	0.20	0.38	0.14	0.33	0.12	0.27
MAXIMUM	0.39	0.62	0.49	0.92	0.53	0.94	0.22	0.43	0.32	0.53	0.38	0.75			0.22	0.79	0.20	0.42
MINIMUM	0.05	0.13	0.05	0.17	0.06	0.13	0.06	0.13	TRACES	0.20	0.05	0.13			0.08	0.18	TRACES	0.13
MEDIAN	0.23	0.37	0.20	0.46	0.22	0.37	0.11	0.25	0.15	0.28	0.20	0.36			0.13	0.30	0.13	0.26

CLADOPHORA INVESTIGATIONS

- 1962 -

A Report of

Observations on the Nature and Control of
Excessive Growth of Cladophora sp. in
Lake Ontario and Lake Erie

John H. Neil

The
Ontario Water Resources
Commission

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

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The contribution made by the Pennsalt Chemical Company and Shell Oil Company of Canada Ltd. in supplying chemicals used for lake tests at half-price is gratefully acknowledged. A number of other companies also supplied chemicals for laboratory investigation free of charge.

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INTRODUCTION

Cladophora is a plant classified under the algae group that is typically found growing attached to the bottom on rocky wind swept shoals of the Great Lakes. It grows in abundance only along certain sections of the Great Lakes shoreline, particularly in the Port Credit to Hamilton area of Lake Ontario and in Lake Erie east from Port Maitland to the Niagara River. Significant *Cladophora* growths also develop in other isolated locations in Lake Ontario, Lake Erie and the St. Lawrence River. Problems caused by *Cladophora* accumulations have also been reported from the United States waters of Lake Ontario and Lake Michigan.

Cladophora growths first appear in the spring during the latter part of May. During the month of June a rapid growth takes place but after the initial development a variety of growth patterns have been observed. The algae may cease to grow when the filaments are a few inches long or they may continue to grow until they are two feet long and cover the bottom completely. In late June and early July onshore winds scour the algae off the bottom and pile it along the shore. The quantity of algae and the time of its appearance along the shore depend on the winds and currents and a heavy growth on the beds may not develop into serious shoreline conditions if the wind and current are not suitable to bring it ashore.

The accumulations may range from only a trace to piles three feet deep and forty or fifty feet wide and these may cover extended sections of shoreline. When the attachment of the algae

to the bottom loosens in late June a favourable wind condition will usually bring in most of the available algae. Subsequently, further and generally smaller quantities will continue to wash in.

When the algae accumulations develop along the shore, that portion of the algae lying on the warm water begins to decompose. Within two or three days the algae looses its typical woolly texture, turns black and in the process of decomposition develops a strong "pigpen" odour. That portion of the algae which has been thrown high enough on the beach to dewater dries, develops a hard cardboard-like consistency and does not create any odour nuisance. A small dipterous fly is attracted to these accumulations and may constitute a nuisance by virtue of their numbers.

The Ontario Water Resources Commission has published previous reports in the years 1959, 1960 and 1961 entitled Cladophora Investigations; Observations on the Nature and Control of Excessive Growths of Cladophora sp. in Lake Ontario and Lake Erie.

RESEARCH PROGRAM 1962

Excessive growths of Cladophora have long been recognized as a problem in both Lake Erie and Lake Ontario and concern has frequently been expressed by municipal officials and property owners alike. As most of the previous work had been done in Lake Ontario, it was decided that in 1962 greater emphasis would be placed on studies in Lake Erie. It was also hoped that generally warmer water and perhaps a more dependable algae crop would facilitate the field testing of algicidal chemicals. More information

was also desirable on the extent of shoreline affected by this problem and some detailed surveys were needed into the specific lake conditions which promoted Cladophora growth.

The testing of a number of chemicals in the field to screen their effectiveness as algicides is time consuming and natural variables render the results difficult to interpret. In order to circumvent these problems it was decided that an attempt would be made to develop a laboratory screening procedure. This procedure proved to be effective and a number of chemicals were studied to determine their relative toxicity to Cladophora.

The two chemicals which were found to be most effective on the basis of laboratory studies were ones which had previously appeared promising in lake trials. For this reason, a sufficient quantity of chemicals was purchased to enable an extensive treatment on growth areas.

Some municipalities, individuals, and beach associations have attempted to clean up accumulated algae along the shoreline using mechanical means. It was felt that these procedures could be improved and that some initial investigation should be made in this regard. Further investigations were also to be attempted into the effectiveness of odour control agents on the decomposing accumulations along the shore.

LABORATORY TESTING OF ALGICIDES

The field testing of chemicals to determine their algicidal properties is subject to many variables such as water movement and uncontrolled temperature and the results of such

experiments are difficult to interpret. Furthermore, wide variations in turbidity makes observations difficult and the rough water typical of the exposed location where Cladophora normally grows frustrates the researcher. In order to screen a number of chemicals rapidly and to determine the effects of various concentrations and exposure time, a laboratory procedure was devised which proved to be very satisfactory.

In this procedure three-litre volumes of the test solutions and controls were prepared with Toronto tap water adjusted to the desired temperature. Fresh samples of the alga were obtained from attached growths in Lake Ontario and portions exposed to the solutions within three hours of collection. After the exposure period the Cladophora was transferred to clean tap water at the same temperature and maintained, with dawn to dusk lighting, for six days. Sub-samples were examined under sixty power magnification, one, three and six days after exposure, and the percentage of cell damage estimated. Results presented here are based on six-day observations, but usually those at three days were identical. Cells were considered damaged when they showed an apparent shrinkage of the cell contents which subsequently disintegrated, leaving only the cell walls visible. With a large percentage of cell damage the alga became muddy-green in gross appearance, slick to the touch instead of woolly, and fragmented easily in water. Controls remained in their original green condition throughout the tests with cell damage less than five per cent in all but one case. The exception was the control held at 71°F, which exhibited terminal cell damage to the extent of 20

per cent of the total mass.

The effects of temperature and length of exposure period on the toxicity of Hydrothol (Penco 47) and Aqualin were examined in the first series of tests. Samples of the alga were exposed to 1 ppm active Hydrothol and 10 ppm active Aqualin at 60, 65 and 71°F, for one and four hours. The percentage of cell damage observed in each case is given in Table I and illustrated in Figure I.

TABLE I - Damage to <u>Cladophora</u> by two algicides at varying temperatures and exposure periods

Product	Percentage Cell Damage					
	1-hour Exposure			4-hour Exposure		
	60°	65°	71°	60°	65°	71°
Hydrothol, 1 ppm active	40	50	90	98	98	100
Aqualin, 10 ppm active	90	95	100	100	100	100

These results indicate that both chemicals were efficient algicides with an exposure period of four hours, effecting at least 98 per cent cell damage. Moreover, there was no great difference in efficiency at the three temperatures. The four-hour exposure was generally more effective than the one-hour period. The exception was Aqualin at 71°F which produced maximum cell damage in only one hour. The data for one-hour exposures indicate differences in efficiency of the chemicals due to temperature variation. The cell damage produced by Aqualin was reduced only ten per cent by exposure at 60°F, rather than 71°, but with the 11° reduction in temperature the damage by Hydrothol decreased from 90 to 40 per cent.

In the second series of tests several algicides were screened for potential toxicity to Cladophora by exposing portions of the algae to various concentrations of each at 65°F, for periods of one and four hours. Formulations tested in this manner included Hydrothol, Aqualin, Hyamine 3500, diquat, paraquat, copper sulphate and NIA 5625, an experimental chemical. Phygon, Penco 191, Garlon and copper sequestrene produced less than 80 per cent damage in four hours in preliminary tests at one concentration, so were not tested further at the time. Results of the series are presented in Table II and III, with those from Table II illustrated graphically in Figure 2.

TABLE II - Damage to Cladophora by three algicides at varying concentrations and exposure periods at 65°F

Product	Concentration ppm active	Percentage Cell Damage 1-hour Exposure	4-hour Exposure
Hydrothol	.25	< 10	50
	.50	10	50
	.75	25	98
	1.00	50	98
Aqualin	1.	10	30
	3.	60	100
	6.	75	100
	10.	95	100
NIA 5625	.10	< 10	40
	.25	20	70
	.50	40	80
	.75	60	90
	1.00	95	100
	3.00	100	100
	5.00	100	100

TABLE III - Damage to Cladophora by four algicides at varying concentrations and exposure periods at 65°F

Product	Percentage Cell Damage 1-hour Exposure Concentration ppm 1	3	5	4-hour Exposure Concentration 1	3	5
Hyamine 3500	<10	50	70	10	75	80
Diquat	50	75	100	50	95	100
Paraquat	50	75	100	95	95	100
Copper sulphate*	0	10	95	<10	20	80

* concentration as salt

The data indicated that by to the concentration where maximum damage occurred at one hour, cell damage was generally more extensive with the four-hour period. An antomology occurred in the case of the copper sulphate (Table III) which appeared to be somewhat more damaging at 5 ppm salt for the shorter contact time. Damage of 95 per cent or higher was observed with four-hour exposures to Hydrothol at 0.75 ppm active, NIA 5625 and paraquat at 1 ppm, and diquat and Aqualin at 3 ppm. This degree of efficiency with one hour of contact required Aqualin at 10 ppm, diquat and paraquat at 5 ppm. The efficiency of the experimental formulation NIA 5625 was still 95 per cent at 1 ppm with the shorter contact time, while that of Hydrothol was considerably lower. The advantage of maintaining the longest possible contact period is obvious.

While these laboratory findings were not expected to be strictly comparable to field conditions, they do indicate the relative algicidal merits of the several chemicals considered, and those worthy of further investigation. Aqualin, diquat, paraquat,

Hydrothol and NIA 5625 exhibited good algicidal properties against Cladophora and fall into this category. The latter three are noteworthy for their activity at l●w concentrations.

LAKE ERIE

Survey of Growth Areas

In May 1962, some general observations were made along the north shore of Lake Erie between Port Maitland and the Niagara River. As a result of this survey, the area fronting on Wainfleet Township was selected from intensive study. Two points, namely Rathfon Point and Grabells Point, were surveyed in detail and later used as test plots for algicide trials. Rathfon and Grabells Points lie three miles and six miles respectively, west of the town of Port Colborne. Measurements were made to determine the length of the rocky shoreline of these points and to mark in the depth contours offshore in order to determine the extent of bottom suitable for algae growth. Grabells Point (Figure 1) was found to have a continuous rocky shoreline for a distance of 4,225 feet. Offshore, the three, six and nine-foot contours were sounded and plotted on a map. The type of bottom in this area was also noted. The total area of rock bottom lying within the nine-foot contour was found to be 133 acres, and there were 84 acres within the seven-foot contour.

At Rathfon Point the rocky shoreline extended for 5,200 feet (Figure 2). At this point the three, five, seven and part of the nine-foot contours were plotted and observations were made on the type of bottom present. A shelf dropping off into water

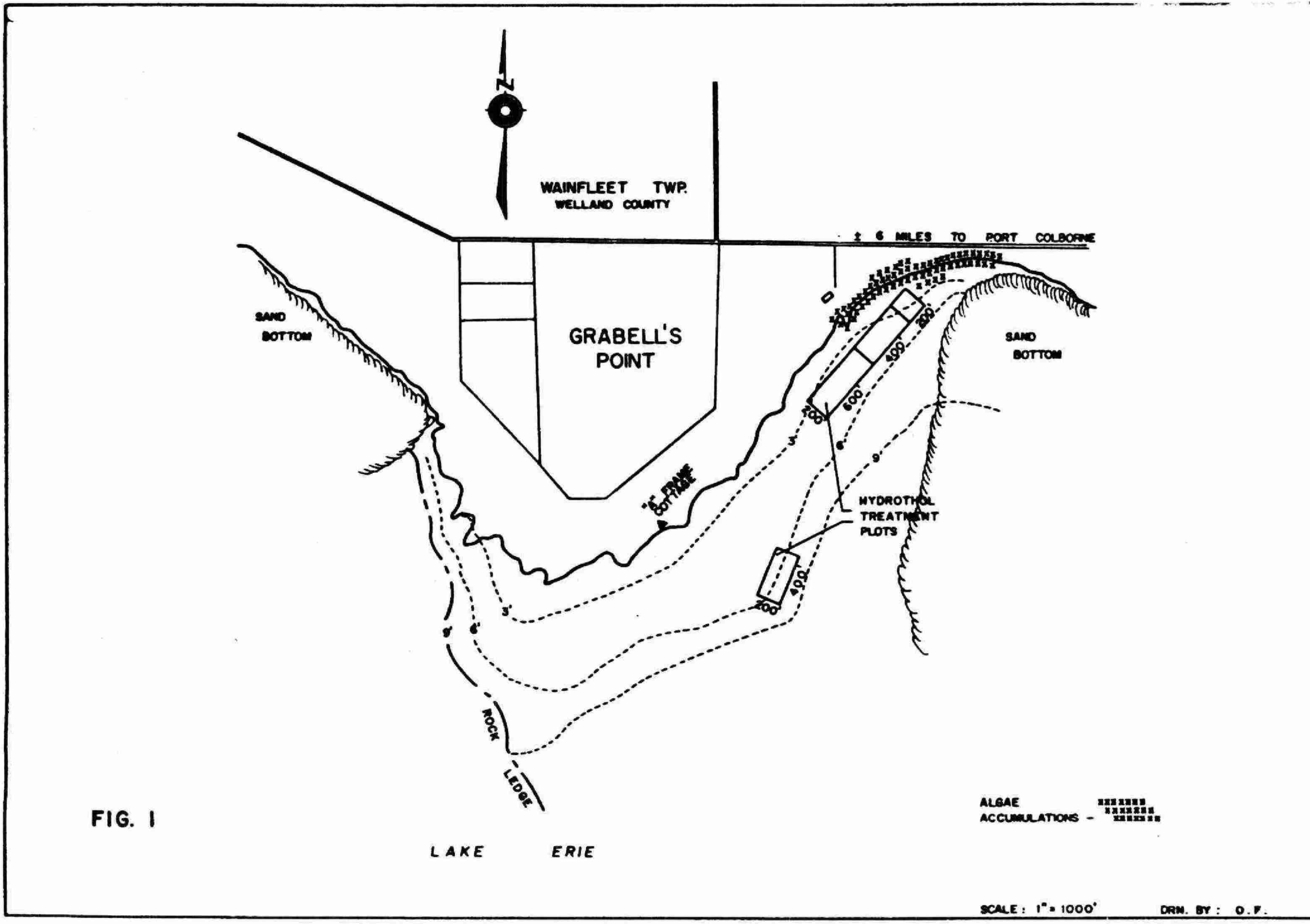

N
WAINFLEET TWP.
WELLAND COUNTY
± 6 MILES TO PORT COLBORNE
SAND BOTTOM
GRABELL'S POINT
SAND BOTTOM
200
400
600
200
3'
6'
9'
"A" FRAME COTTAGE
HYDROTHOL TREATMENT PLOTS
400
200
3'
6'
9'
ROCK LEDGE
ALGAE ACCUMULATIONS -
LAKE ERIE
SCALE: 1" = 1000'
DRN. BY: O.F.

FIG. 1

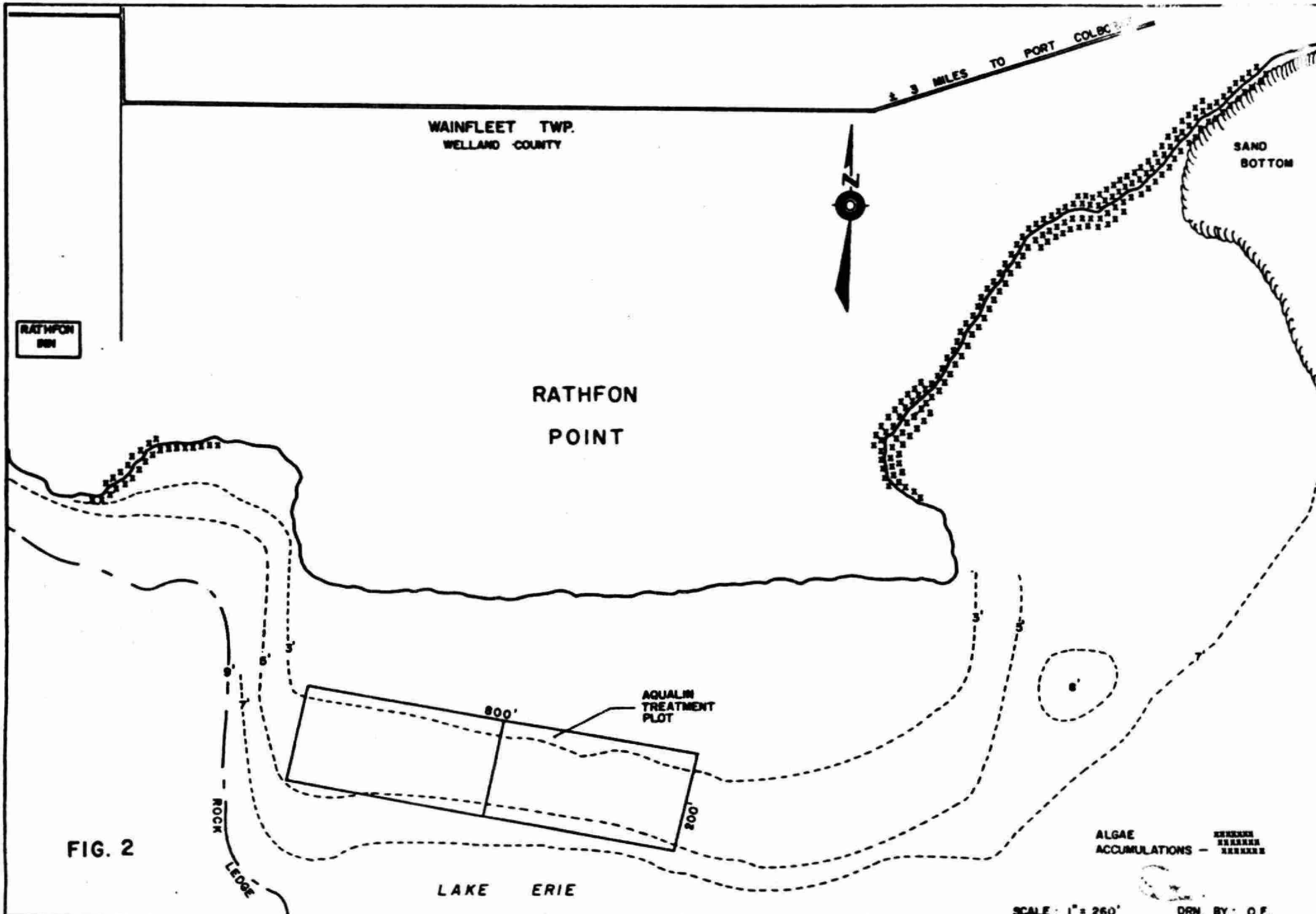

± 3 MILES TO PORT COLBORNE
WAINFLEET TWP.
WELLAND COUNTY
N
SAND BOTTOM
RATHFON INN
RATHFON POINT
3'
5'
9'
7'
3'
5'
6'
7'
800'
200'
AQUALIN TREATMENT PLOT
ROCK LEDGE
LAKE ERIE
ALGAE ACCUMULATIONS –
SCALE : 1" = 260'
DRN. BY : O.F.

FIG. 2

greater than nine feet in depth followed the shore very closely along the westerly 600 feet of Rathfon Point. The width of the shoal then increased and extended in an easterly direction. The central portion was essentially solid rock whereas the easterly area was composed of mixed bedrock and a boulder-sand bottom. This ultimately gave way to a pure sand bottom. A total of 20.1 acres of continuous bedrock where the depth was less than seven feet was calculated to be present and there was an additional 26 acres of bottom composed of a boulder-sand mixture.

Observations on Cladophora Growth

The first observations on the growth areas were made on May 17th, at which time the algae had just started to develop. Thereafter, observations were made at approximately weekly interval. During June the crop increased and on June 6th, detailed observations were made of the Cladophora conditions on both Grabells Point and Rathfon Point by scuba diving. The rocky bottom in both of these areas was found to be almost 100% covered with Cladophora, having a filament length of three to five inches. Continuous observations were made offshore to the point where the algae ceased to grow. This occurred at a depth of about thirteen feet. There was an obvious lessening of the length of filaments and the percentage of bottom coverage between nine and thirteen feet. The total crop had a light green appearance with the exception of the vicinity of Rathfon Point immediately facing Rathfon Inn where the beds were noticeably darker in colour. Large numbers of fish were noted, particularly at Grabells Point. Bass nests were common

in the algae beds and newly hatched fry of an unknown species were numerous, particularly in the near shore areas.

On June 27th, at the time of chemical applications on Grabells Point the appearance of the algae had changed somewhat. In the areas near shore particularly, the beds in gross appearance had a lighter green to almost a straw colour. On close examination, most of the basal parts of the plants were green changing to the straw colour towards the end of the filaments. Growth had continued in the interval and the filaments on the beds were as much as ten inches in length. On July 6th, the gross appearance of the algae had lightened a little more and there did not appear to be any extensive additional growth on the beds. On July 13th, the algae had not grown any more. There was still the bleached appearance to extensive areas of the beds and there was evidence that the algae had loosened considerably on the bottom. The algae loosened from the bottom and twisted into rope-like strands, or collected in loose balls on the bottom. This left some parts of the bedrock exposed. Shortly after this date, onshore winds began to blow algae accumulations ashore and by the 24th of July most of the crop from these two points was piled up along the shore and beginning to decompose (see Figures 1 and 2). On July 24th, the beds were carefully observed by diving from the shore to the outer extremity of growth on Grabells Point. The bottom from the shoreline to nine feet was essentially clear of algae. The rock and cobblestone bottom which had been completely covered before, was now clear with the exception of some brown bits of obviously unhealthy algae. After nine feet the algae was green, six to

eight inches in length, generally not too firmly attached and had much the appearance as the general crop on July 13th. It would appear that the waves and currents that had dislodged the crop at depths of less than nine feet had not affected the algae in the deeper water.

Further observations were made of the algae growths on these points on July 30th, August 9th, 23rd and September 10th and no significant regrowth was observed to develop. A few strands of light green algae did develop but only a very small percentage of the bottom was covered.

Further accumulations arrived at the shoreline after the initial cleaning of the beds that occurred between July 13th and July 24th, but these were minor in nature and never assumed the proportions of the initial deposits. On July 23rd, a survey of approximately sixty miles of shoreline was made to determine the position and extent of the algae accumulations on that date. Algae was found to have accumulated in eighteen places affecting a total linear beach line of about eight miles.

The condition of algae growing in beds in the vicinity of Crystal Beach was observed on several occasions. On July 5th the algae growing on Point Abino had much the same appearance as that at Rathfon and Grabells Points. The Cladophora growing near the easterly limits of the village of Crystal Beach, in the vicinity of the sewer outfall and further eastward for at least one mile, was found to be much more lush in appearance. The filaments were longer and the green colour was much darker. No large accumulation came ashore on Point Abino but the usual heavy

crops of algae drifted in during the summer at Crystal Beach.

On September 24th, the bottom throughout this same area was still covered by a healthy dark green mat of algae.

Algicide Trials

The selection of chemicals for trial use in Lake Erie was based on the laboratory tests and previous field studies. The laboratory tests indicated that Hydrothol and Aqualin would probably be the most effective and economical algicides. In previous years a number of field trials were made using 0.25 ppm and 0.5 ppm Hydrothol and 3 to 10 ppm Aqualin. Some fairly good kills had been obtained but the results were not consistent.

In Lake Erie it was anticipated that the warmer water would permit early treatments and allow for retreatment should subsequent growths develop. The applications in Lake Erie were to be made as soon as a significant growth was present and the water temperature high enough to permit effective treatment. The concentrations of the algicides tested were to be sufficiently high to secure effective algae control and the areas treated were to be large enough so that water movement along the shore would not move the treated water off the plot before the chemical had acted. The treated areas were to be observed on a regular basis and if new crops of algae developed within the plots, subsequent applications of chemicals would be made. In this way the frequency of treatment necessary for algae control would be established.

Hydrothol Application

The area chosen for the treatment with Hydrothol lay on the east side of Grabell Point, over a section of bottom that was entirely covered with Cladophora, (Figure 1). The treatment of 0.93 ppm was applied on June 28th to two plots, (1) an area 1200 feet by 200 feet having depths ranging from two to four feet with a total volume of 18 acre-feet, and (2) a plot 200 feet by 400 feet ranging in depth from five to seven feet and having a total volume of 12 acre-feet. The weather was clear and calm, and the water temperature had risen to 72°F in the shallow plot and to 68°F in the deeper area. Dye placed in the water to measure currents indicated that there was little or no water movement. At the time of treatment the algal filaments were six to ten inches long. Most of the algae was light green in colour, though some bleaching was evident towards the tips of the filaments.

The liquid chemicals were applied from the Commission boat, using a centrifugal pump fitted with a dual intake. The algicides were metered into the diluting volume on the suction side of the pump and the mixture forced out through a distribution boom. This boom was fitted with nozzles which trailed on the bottom behind the boat and released the algicides directly into the Cladophora bed.

Fish were numerous in the treated areas. Perch, Perca flavescens, carp, Cyprinus carpio, smallmouth bass, Micropterus dolomieui dolomieui, and alewives, Pomolobus pseudoharengus, were the principal species observed and a large number of recently hatched fry were sighted. During and following the treatment a

few fish were noted in the treated section. No mortality of any kind was found even among the recently hatched fish. Laboratory studies have indicated that Hydrothol is toxic at concentrations less than those used for Cladophora control. It has not however, caused any known fish mortality when used for Cladophora treatment.

The first observation of the treated area was made eight days after treatment on July 6th. The boundaries of the treated plot were evident from shore as the whole treatment area had a white appearance in contrast to the olive-green colour of the surrounding area. Close examination revealed that the algae filaments were bleached and microscopic examination of the individual cells showed them to be disrupted and to have lost most of their cell content. Some apparently viable green cells remained near the base, close to the point of attachment to the rocks. The algae had a slimy feel in contrast to a natural woolly texture, which indicated that the material was breaking down in place rather than being loosened from the rocks and perhaps going ashore. The algae on the plot in deeper water was also affected by the Hydrothol but there was still some green in evidence throughout the plot.

The next observation was made on July 13th, seven days later, and at this time further deterioration of the algae on the two plots was evident. The rock bottom and cobblestones which had previously been obscured were now apparent particularly in the shallower plot. Some green basal cells were still evident in the area to which chemical had been applied but no evidence of re-growth was found. The algae in the area surrounding and unaffected

by the treatment showed a decline in the vigour in the crop and as was previously described, was beginning to loosen from the bottom and "rope up".

The next inspection was made ten days later on July 24th. On this day most of the loose algae from the entire point had been blown ashore so that both the plots and the surrounding area were relatively clean. There was no observable difference between those areas which had been treated and the surrounding beds. Subsequent inspections were made on August 8th, 23rd and September 10th. Some small fringe growths developed on the bottom, late in the summer on Grabell Point outside the areas treated. As little or no growth took place in the treated areas, it was believed that some continuing control had been obtained in the areas treated. This observation, however, could not be positively established because of the general poor growth over the entire area.

Aqualin Treatment Plot

On July 6th, Aqualin was applied to a plot fronting on Rathfon Point. The area treated was 200 by 800 feet with depths ranging from two to five feet and a volume of 12.9 acre-feet (Figure 2). This application was made early in the morning when the water was calm and the temperature 68°F. Dye tracer was used to measure water movement and this was determined to be westerly at 10 feet per minute. The growth of algae covered 90% of the bottom and the filaments were approximately six inches long. Some bleaching was again apparent in the terminal areas of the filaments but the bulk of the algae was light green in colour. The Aqualin

was metered through the apparatus previously described to provide a concentration of 12 ppm.

At the time the Aqualin was applied, no fish were observed in the plot. During the treatment and immediately afterward, some bullheads, Ictalurus nebulosus, were observed to surface and some of these subsequently died. A total of perhaps 40 were killed in all.

The first observation on the effect of the treatment was made on July 13th, seven days later. The area to which the chemical had been applied was immediately apparent from the bleached white appearance. Closer examination made by diving within the plots showed the algae to be completely white and there were no remaining green cells in the basal portions of the filaments. The line of demarcation at the east end of the plot was sharp while on the westerly edge and beyond the outside edge there was an extended kill. This was the result of water currents and diffusion carrying a toxic concentration of the chemical considerably beyond the boundary of treatment in a 'downstream' direction. Outside the plot to the west and offshore the algae was at first totally killed, then there was less and less effect with the basal portions of the filaments becoming greener until the green colour extended to the terminal cells. In all, an area perhaps half again as large as the original plot was seriously affected.

The next observation was made on July 24th ten days later. In the interval the storm which had removed the algae crop from Grabell Point had the same effect on Rathfon Point and the algae from both the treated and untreated areas alike had been

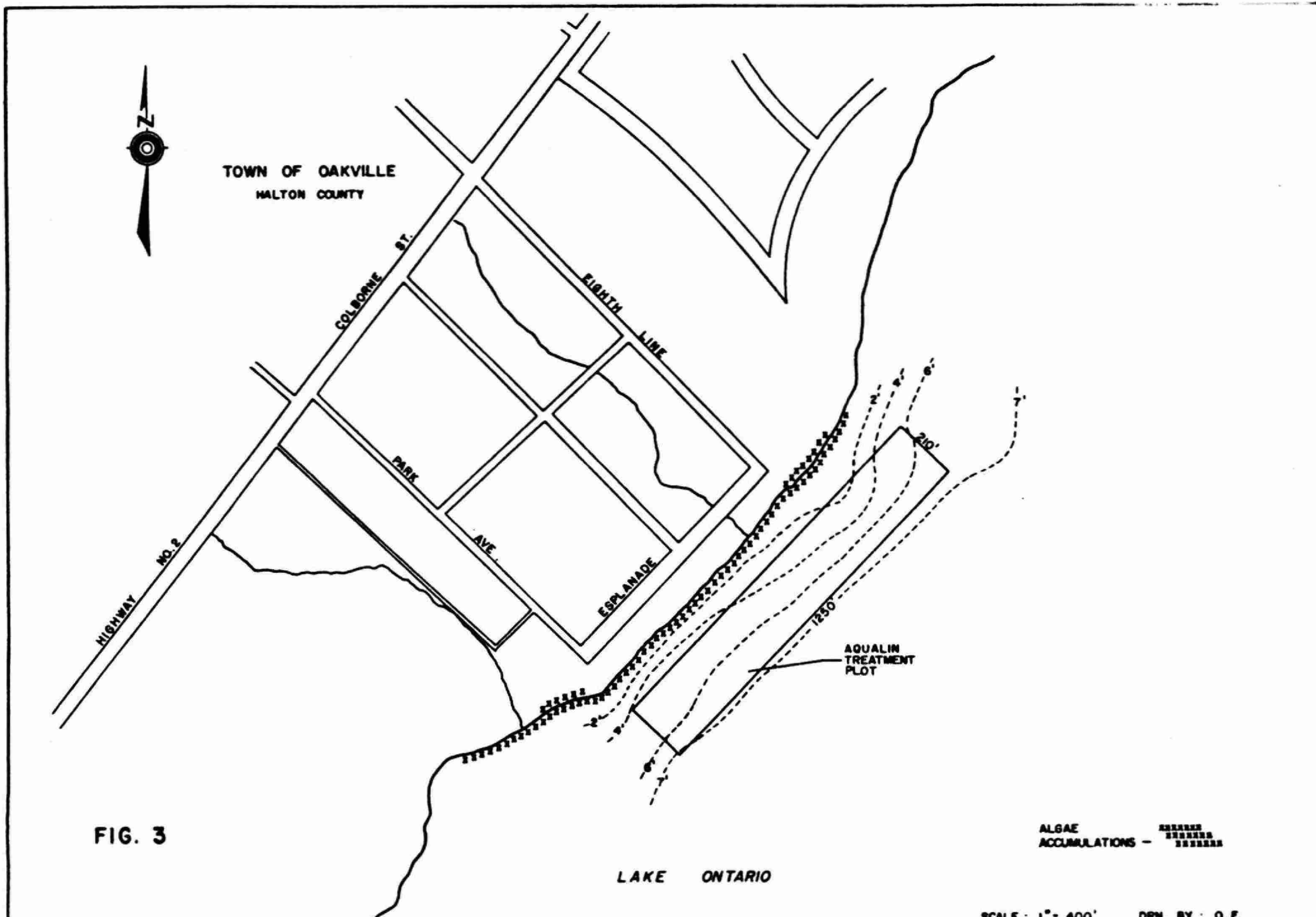
removed and was piled in the cove at the easterly end of the point (see Figure 2). Subsequent investigations on July 30th, August 8th and 23rd and September 10th showed that only a minor regrowth had occurred. Again there was evidence of control of regrowth within the treated area but this could not be positively established.

LAKE ONTARIO

Observations of Cladophora Growth

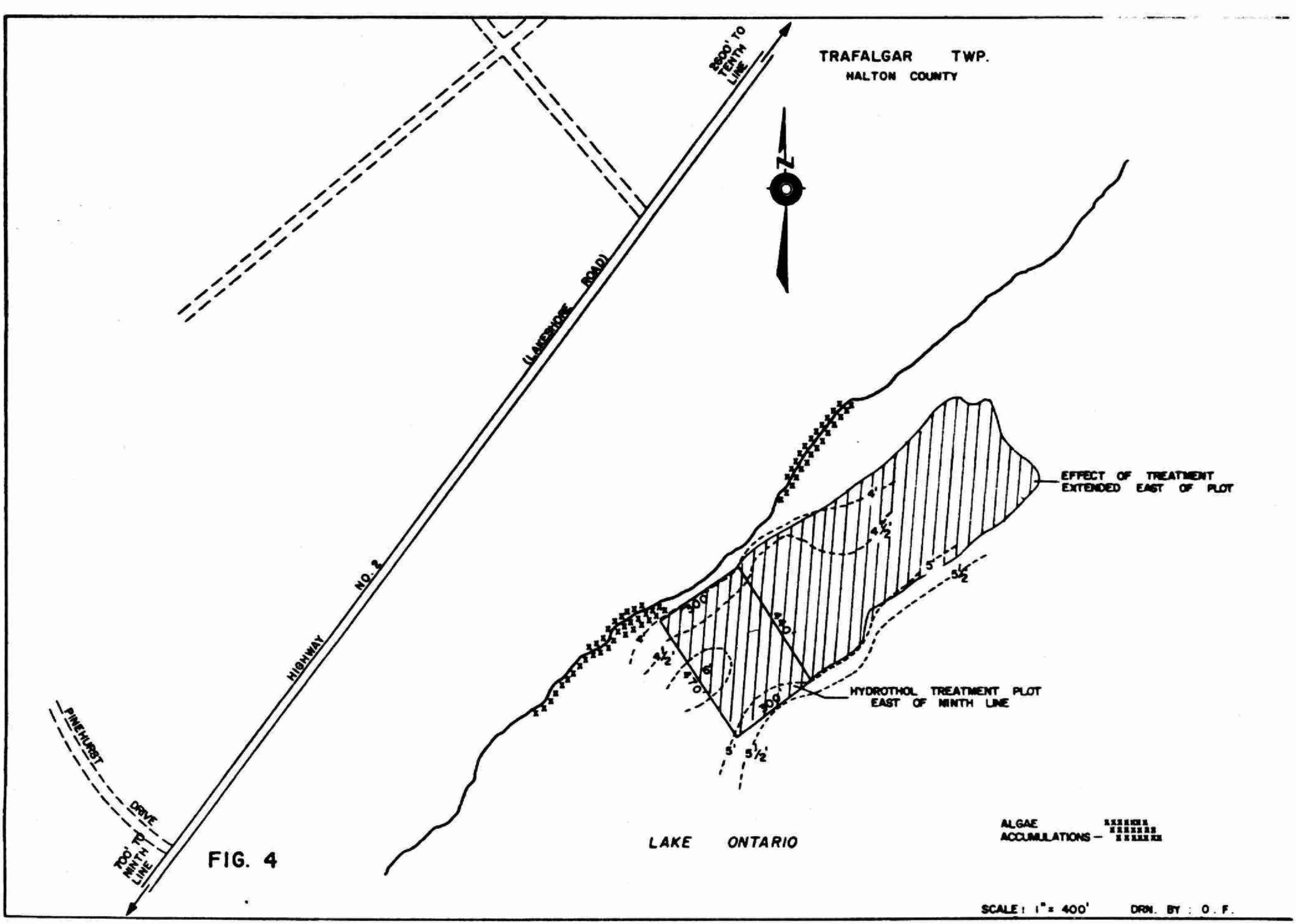
Less detailed observations were made of the conditions of Cladophora growths in Lake Ontario in 1962 than in the three previous years, because of the decision to undertake most of the experimental work in Lake Erie. The growth was known to have been established by May 29th since samples of algae for laboratory tests were collected from Lake Ontario at Oakville at that time. On this date filaments three or four inches in length were found in the areas near shore.

On July 11th detailed observations were made by scuba diving in the area off Park Street and near the point east of the ninth line (Figure V). The observations at Park Street were made by beginning close to shore and swimming outwards, following the bottom, until the algae ceased to grow. The growth from 0 to 12 feet was generally heavy, covering almost 100% of the bottom with filaments eight to twelve inches in length. Algae covered the bottom evenly and was attached, though not strongly as the bulk of the material could be gathered readily by hand. After 12 feet, the growth was less dense, the length of filaments was shorter and open areas were present. There was, however, still a considerable



TOWN OF OAKVILLE
HALTON COUNTY
N
COLBORNE ST.
HIGHWAY NO. 2
PARK AVE.
EIGHTH LINE
ESPLANADE
2'
4'
6'
7'
210'
1250
AQUALIN TREATMENT PLOT
LAKE ONTARIO
ALGAE ACCUMULATIONS –
SCALE : 1" = 400'
DRN. BY : O.F.

FIG. 3



TRAFALGAR TWP.
HALTON COUNTY
2800' TO TENTH LINE
HIGHWAY NO. 2 (LAKESHORE ROAD)
PINEHURST DRIVE
700' TO NINTH LINE
EFFECT OF TREATMENT EXTENDED EAST OF PLOT
HYDROTHOL TREATMENT PLOT EAST OF NINTH LINE
LAKE ONTARIO
ALGAE ACCUMULATIONS
SCALE: 1" = 400'
DRN. BY: O. F.

FIG. 4

crop of algae on the bottom. At 23 feet, the algae disappeared rather abruptly. Large boulders extending above the 23-foot level had growths of algae on the upper surface but the bottom, while still clean bedrock and boulders, supported no algae.

A similar survey was made at the rock shoal east of the Ninth Line (Figure VI). From 0 to 12 feet the bottom was covered almost 100 per cent by a luxuriant rich green growth. In the shallower areas some of the algae was balled-up and twisted into rope-like masses extending to the surface from a depth of about four feet. The remainder of the area was uniformly covered to a depth of eight to twelve inches but again the filaments were not strongly attached to the bottom. No observations were made at depths greater than twelve feet.

Generally observations on <u>Cladophora</u> beds and shoreline accumulations were noted on the weekly sampling surveys that the Commission carried out between Port Credit and Hamilton. Many shoreline accumulations were noted and odour resulting from the decomposition of this material was common.

In connection with the evaluation of the efficacy of algicides applied in the Oakville area, a number of observations were made of the general algae conditions in the vicinity of the treatment plots. While turbid water and very low water temperatures hampered these observations, lush <u>Cladophora</u> beds are known to have remained established until early October at least.

Algicide Trials

Sufficient chemicals were purchased to permit two treat-

ments of the areas in Lake Erie, should this have been necessary. By the middle of August it was apparent that no algae was growing in the general areas where the treatment had previously been applied and for this reason chemical was available for testing in Lake Ontario.

Aqualin Treatment Plot

On August 21st an application of 7 ppm of Aqualin was made to a plot 1250 by 210 feet opposite Park Street (Figure V). The depth varied from four to seven feet and the total volume was 33 acre-feet. The day that the Aqualin was applied was calm, the water temperature 59° and there was a slow easterly movement of the water at three to five feet per minute. The algae growth was eight to twelve inches long, dark green in colour and covered 95% of the bottom. The chemical was applied using the apparatus previously described so that it was applied directly into the Cladophora growth.

Before treatment, a number of carp, Cyprinus carpio, were observed in the area. During the treatment a number of bullheads, Ictalurus nebulosus, were killed. It is likely that a number of other fish were also affected, as herring gulls were attracted to the area and were observed to be feeding during the final stages of the treatment.

Observations of the treated areas were attempted on August 31st, September 6th, 10th and 26th. On August 31st the water was very turbid but samples scraped from the bottom within the plot showed some evidence of deterioration. This was taking

place in situ as much of the material brought up had a brown appearance and a slimy feel. On September 6th, the water was still turbid but diving indicated that some change had taken place though the kill was by no means complete and patches of healthy algae remained within the treated area. A further attempt to evaluate the effectiveness of this treatment was made on September 10th but the water was again turbid and as the water temperature was 48°F on this occasion, only limited observations could be made by diving.

On September 26th, thirty-six days after treatment, the water was very clear and good observations could be made from the surface. At that time, the tracks of the hoses which carried the chemicals into the water and produced a local kill could still be seen, but healthy growths occurred between these tracks. It was estimated after comparing the treated area with the growths in the surrounding beds that fifty per cent control had been achieved at that time.

Hydrothol Treatment Plot

On August 24th, Hydrothol was applied to a plot 300 by 470 feet at a concentration of 1.1 ppm on the shoal east of the Ninth Line. The water depth in this area was four to six feet and the total volume treated was 16.2 acre-feet. The water temperature at the time of treatment was 68°F and a current of seven feet per minute was measured, moving parallel to shore in a north-easterly direction. There was some swell remaining from a blow on the previous day and while the water was turbid it was estimated by

diving that 75% of the bottom was covered with a growth seven to twelve inches long and lush green in colour.

No fish mortality resulted from this chemical treatment.

The first observations made under the adverse conditions previously described in the section dealing with Aqualin, indicated that a good kill of the algae had been achieved. Samples taken from the bottom and limited observations made by diving, showed that all samples had a slimy texture and were bleached or brown in colour. Rocks awash at the surface in the treated area that normally were ringed by a heavy growth of Cladophora were completely cleared and there was evidence that the effect extended towards the north-east in the direction that the current was moving the day the chemical was applied. On September 26th, thirty-three days after treatment when the water was clear enough to permit good observations from the surface, virtually no algae remained in the treated area or in a further 600 feet to the north-east. The algae growing away from the treated area retained the characteristic green colour. It was estimated that the algae kill from this treatment was 95% effective.

CONCLUSIONS FROM CHEMICAL STUDIES

Hydrothol gave good to excellent control at concentrations of 0.93 and 1.1 ppm in both Lake Erie and Lake Ontario. The excellent results in Lake Ontario occurred in a water temperature of 68°F and at a time when there was some turbidity and a water current of seven feet per minute. Previous Hydrothol treatments in 1961 also provided some control of Cladophora at lower con-

centrations and when the water was as cold as 60°F.

Aqualin gave good control in Lake Erie at 12 ppm in 72°F water but unsatisfacotry control in Lake Ontario at 7 ppm when applied to water 59°F.

The following cost estimated has been made for treating one acre of water averaging four feet in depth.

Hydrothol	-	concentration 1 ppm	=	\$ 65.00
Aqualin	-	concentration 10 ppm	=	\$ 70.00

The cost of applying the chemical is not included in these figures.

These are concentrations which are known to have provided good control under favourable treatment conditions. It is probable that good control could be achieved at a lower rate by choosing a time when water temperatures and water movement are favourable and when extensive applications could be made at one time.

While the cost figures quoted are comparable, Hydrothol has certain inherent advantages in that it is less toxic to fish, is easier to handle and can be applied in a liquid or granular formulation from aircraft.

The laboratory studies have indicated NIA 5625, copper sulphate, Paraquat and Diquat to exhibit algicidal properties against Cladophora. The experimental chemical NIA 5625 only became available late in the season and sufficient quantity was not available for field testing. Laboratory results have shown it to be at least as effective as any other product tested to date. Further studies will be taken to determine its effectiveness and cost for Cladophora control.

Copper sulphate has been thoroughly tested in the lake.

Concentrations up to 10 ppm have not shown any lasting effect and for this reason it cannot be considered as a suitable algicide for the control of Cladophora. Paraquat and Diquat have demonstrated a toxicity to Cladophora at 5 ppm in the laboratory study. The cost of treatment with either of these chemicals at this concentration would not be competitive with that of Hydrothol or Aqualin.

TESTING OF DEODORANTS

Two bactericidal products were tested during the summer of 1962 to determine their effectiveness in reducing septic odours caused by the decomposition of shoreline accumulations of Cladophora. These products, Hyamine 2389 and Ozene, were applied on July 30th.

Hyamine 2389

Hyamine 2389 is a quaternary ammonia compound which is used as a disinfectant, an algicide and a deodorant in sewage plants and garbage dumps. A strip of decomposing algae approximately 300 feet long and varying in width from 50 to 100 feet wide was treated with five U.S. gallons of this product. The total area treated was estimated to be one half acre and the depth of algae on the plot varied up to three feet, with an average depth of one foot. A similar adjacent accumulation occurred nearby, which extended out to open water. This was left untreated to provide a control area.

The odour during the period of treatment was extremely foul, characterized by a pungent sulphide smell.

The five gallons of Hyamine 2389 applied by adding one

pint of the bactericide to each 45 gallons of water and spraying this under pressure, using a gasoline-operated portable pump. The pump was placed in a light aluminum skiff which was dragged over the surface of the rotting algae to permit treatment of the entire area.

The plot was revisited on the day following treatment and there was a definite decrease in odour on the area treated. It was necessary to bend down close to the surface of the plot to detect a distinctly offensive algal odour. The odour from the untreated control area adjacent to the plot, was very strong, just as it had been the day before. An inspection of the plot on the ninth day following treatment revealed that little smell could be noticed either from the treated or untreated areas since the wind was blowing out to the lake. Occasionally an unpleasant whiff of decomposing algae would be noticed and it was doubtful whether the treatment was providing any beneficial effect at this time. The cottages facing the plot were unoccupied so that it was not possible to obtain any comments concerning the effectiveness of the treatment during the week following the application of Hyamine.

Ozene

Ozene, a water emulsifiable formulation of Orthodichlorobenzene, was applied to a small accumulation of algae that was estimated to occupy an area of 2500 square feet. The average depth of the decomposing algae was six inches. One gallon of Ozene was applied by mixing each of four quarts with 45 gallons of water and spraying this under pressure, as with the Hyamine.

The accumulation was distinctly odorous before the Ozene was applied but the smell became masked by the antiseptic smell of the Ozene as the treatment progressed.

On the day following the treatment the antiseptic smell was still very noticeable and there was a definite reduction of the offensive algal odour. Eight days later there was no apparent benefit. Reports from cottagers in the immediate vicinity indicated that a strong creosote odour persisted for two days following the application. It was concluded that the smell of the Ozene in supplanting the odour of the decomposing algae did not provide a satisfactory solution to the problem.

MECHANICAL BEACH CLEANING

Several municipalities fronting on Lake Erie have attempted to gather and dispose of accumulations of algae as they are washed ashore. A variety of methods have been employed which have included at least the following procedures; hand raking, bulldozing into piles and burying, raking or scraping into windrows for subsequent loading onto trucks manually or by front-end loader, or scraping and gathering with a front-end loader for piling above the water line or for subsequent disposal by truck. Attempts have also been made by individuals to wash down the rocks with high pressure hoses and to dislodge accumulations of decomposing algae using the wash of an outboard motor.

Many areas where algae accumulates are sufficiently rough, by virtue of shelving rock or boulders strewn on the beach, that it is difficult or even impossible to employ conventional

TABLE IV - Summary of Information from Beach Cleaning Questionnaire

	DATES OF REMOVAL 1962	NO. OF HOURS WORKED	ESTIMATED NO. OF CUBIC YARDS REMOVED	METHOD OF DISPOSAL	EQUIPMENT USED AND COST	HAND LABOUR COST	TOTAL COST OF OPERATION
Rock Point	August 3, 4	32	15	Trucked away	½ ton truck $ 25.00	$ 45.00	$ 70.00
Cedar Bay Walnut Park	July 12, 13, 24, 26, 30, 31 Aug. 1, 2, 4, 6, 8, 9, 10, 11, 18, 22, 23, 31 Sept. 1	76¾	100	Piled on shore	Tractor and front end loader $ 278.00	$ 9.70	$287.70
Grabells Point	August 8	10		Piled on shore and pushed into lake	Tractor with rake $ 99.50	$ 20.00	$119.50
Morgans Point	August 9	6		Picked up on shore			
Crystal Beach	June 29 July 6, 13, 16, 19, 23, 25, 29 Aug. 3, 6	173	185	Trucked away and some piled on shore -	Tractor with rake and bulldozer and truck $316.95	$259.50	$576.45

equipment. Also, after the algae has started to decompose, it loses its woolly structure and becomes sludge-like and in this condition is impossible to rake, gather or load.

It was felt that improvements could be made to the conventional types of collecting devices and for this reason a survey was made to obtain information from the beach associations and municipalities which had attempted collection and disposal of shoreline accumulations during the summer of 1962. To obtain this information a questionnaire was sent out and four replies were received. Table IV provides a summary of the information obtained.

Rock Point

Rock Point, located in Sherbrook Township, is a public provincial park operated by the Department of Lands and Forests. As heavy accumulations do not normally occur and since manpower is available, collections are normally made by hand. The procedure employed is to gather the material along the waters edge with manure forks, pile it onshore and allow it to drain before trucking it away. In 1962, collections were necessary on two days and 32 hours of hand labour was required to remove 15 cubic yards. The total cost of this operation was estimated to be $70.

Figures for 1961 were included, which indicated that the condition had been considerably worse in 1961. In that year, shore collections were required on five occasions and a total of 33 cubic yards of algae were removed after 73 man-hours of labour.

Cedar Bay (Walnut Park Section)

Cladophora accumulations along the shore have been a

continuing problem to the summer residents of Walnut Park for a number of years. During the past two or three years an active beach association has contracted for the removal of boulders near the waters edge by bulldozing, in order that algae drifting ashore can be collected mechanically.

While a variety of farm equipment has been employed, most of the collections have been made using a front-end loader on a farm tractor, modified to improve the operation of collecting and lifting the algae. In 1962, all or part of nineteen days were used in gathering the algae that had drifted ashore and depositing it in piles on the beach above the high-water line. This procedure was found to be quite successful though pockets of the algae were difficult to remove in some areas of shelving rock. A total of 77 hours was used in gathering and piling an estimated 100 cu. yards of Cladophora. The total cost of the algae control programme in 1962 was $287.70.

Grabell Point and Morgans Point

On August 8th and 9th a deisel farm tractor was employed in a cleaning operation sponsored by Wainfleet Township. The algae had been ashore since the latter part of July and much of it was in an advanced stage of decomposition. Some of the material could be removed but a considerable quantity had to be pushed back in the lake. This was reported to be effective in controlling the nuisance along this portion of the shoreline as the material disappeared shortly and did not wash up on the shore again. A total of 16 hours was required for these operations and the cost was $119.50.

Crystal Beach

Cladophora was washed ashore and removed on ten occasions from shoreline owned by the Village of Crystal Beach. This operation necessitated 282 hours of labour and an estimated 185 cu. yards of material were handled. The total cost of this operation was $576.45.

This area at Crystal Beach probably receives consistently the greatest accumulations of algae in Lake Erie. The portion of beach most affected is used extensively for bathing and an effort is made by the municipality to keep it as clean as possible. In spite of these efforts, the methods used remove only the gross accumulations of algae and leave pockets around the shelving rock and mixed in the sand.

It may be concluded from the observations made and the information received from the municipalities using mechanical collection methods, that this procedure is effective in removing gross accumulations. Hand labour is the only method presently available which will completely clean the beach. Mechanical cleaning is effective only when the algae is first brought ashore and before decomposition takes place. Its efficiency can be improved if obstructions, such as boulders, are removed from the beach. This method is relatively inexpensive in comparison with chemical treatment of algae on the beds in the lake and while it is not entirely satisfactory, a tolerable condition can be achieved.

There is considerable room for improvement in techniques of collecting and disposing of the algae which would make this

procedure more efficient and probably less expensive. It is recommended that further studies be planned in this regard.

SUMMARY

Detailed surveys of growth areas were made at Rathfon Point and Grabell Point in Lake Erie. Algae was found to grow to a depth of about 13 ft. In depths greater than 7 feet the quantity of algae was considerably less. At depths greater than 9 feet wave action did not dislodge the crop. The total area of growth having a depth of 7 feet or less was 84 acres at Grabell Point and 20 acres at Rathfon Point. These were typical of many rocky points which support growths that eventually cause malodorous conditions and many larger and smaller areas are to be found in the easterly end of Lake Erie. One cursory survey made on July 23rd indicated that nuisance conditions occurred at 18 places, affecting 8 of the 60 miles of shoreline surveyed.

Observations in Lake Ontario indicated that algae grows in quantity to a depth of 23 ft. Estimates of the total growth areas have been made in previous reports (Cladophora Report, OWRC 1961).

Cladophora developed an unhealthy appearance early in July in all of the area of Lake Erie under observation with the exception of Crystal Beach. This was manifested by a weakening of the filaments and a bleaching of colour. Shortly after this time accumulations began to come ashore and while some growth continued, no pronounced crop developed during the remainder of the season. The algae in Lake Ontario was dark green in colour

and continued its growth throughout the summer.

A laboratory method of testing the effectiveness of various algicides against Cladophora was devised. A total of 70 tests were made using a number of chemicals at different temperatures, exposure times and concentrations. These laboratory studies showed Hydrothol (Penco 47 or TD 47), Aqualin and NIA 3625 to be the most effective chemicals.

Field studies indicated that Hydrothol was effective in killing Cladophora in tests made in Lake Erie and Lake Ontario. Aqualin worked well in Lake Erie but was not satisfactory in Lake Ontario. Both chemicals cost about $65. per acre of lake bottom treated at the concentration used. Some reduction in this cost may be possible when large applications can be made under favourable environmental conditions.

Hydrothol has certain advantages over Aqualin in that it is easier to handle and may be applied by aircraft. While both chemicals are toxic to fish, field tests have shown Hydrothol to be less hazardous in this regard. Sufficient quantities of NIA 5625 were not available for field testing in 1962. It is toxic to fish in about the same range as the Hydrothol. Laboratory studies indicate that it may be effective in controlling algae at the same or lower concentrations than Hydrothol.

Two chemicals were applied to control odours associated with decomposing accumulations of algae. Hyamine 2389 provided some temporary relief. Ozene gave some immediate odour supression but the residents objected to the antiseptic smell of the compound.

A questionnaire was circulated to parks, municipalities and beach associations that collected algae accumulations mechanically for disposal and four replies were received. The total quantity estimated to be removed in three of the four reported beach areas was 400 cubic yards. Th total number of hours work involving power equipment was 212 and 229 hours were spent in removal by hand labour. Th total cost of these four operations was $1,053.65. It was generally concluded that this method of alleviating the nuisance of accumulated algae at the shoreline was effective where local conditions permitted the use of mechanical equipment, but that better methods could probably be devised.

RECOMMENDATIONS

1. Field tests of the algicide NIA 5625 should be carried out for Cladophora control, to determine its effectiveness and cost.
2. Laboratory screening of likely chemicals should be continued and field tests carried out on any which appear to hold promise.
3. A study should be undertaken to develop equipment suitable for the removal of algae accumulations that are washed ashore. It is proposed that this be carried out by mechanical consultants such as a university engineering group working under the direction of the OWRC. Sufficient funds would be required to permit field trials of equipment, modified or constructed to the specification of the consultant.

4. Where Cladophora control is undertaken by commercial applicators for municipalities, the Commission should provide technical assistance and an appraisal of the effectiveness of the treatment for that municipality.
5. The Commission should continue its studies into factors promoting the growth of nuisance quantities of Cladophora.

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DISTRIBUTION, ENVIRONMENTAL REQUIREMENTS AND SIGNIFICANCE OF *CLADOPHORA* IN THE GREAT LAKES

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Abstract. Excessive growths of *Cladophora* sp. along certain sections of the Great Lakes shoreline create serious nuisance conditions which affect the use of water for recreational, industrial and municipal purposes. Information on the ecology of this algae was collected as part of a study directed towards the development of control measures. The presence of *Cladophora* sp. is dependent on a suitable substrate for attachment, water movement, adequate light, and nutrients in excess of those normally available in the waters of the upper Great Lakes. Lakes Ontario and Erie have sufficient inherent fertility to support marginal growths, but where local nutrient sources are available, production increases. Phosphorus applied to a location providing suitable physical conditions but devoid of *Cladophora* sp. resulted in the establishment of a sizeable area of growth. The results of attempts at control are also discussed.

INTRODUCTION

Branched filamentous green algae of the genus *Cladophora* are distributed throughout the world in both fresh and salt water. In fresh water, species may be found in ponds and streams and in both the littoral and profundal regions of some lakes. The taxonomy of the genus is difficult because of a considerable degree of morphological variation within a species, apparently a results of varying environmental conditions (Prescott 1951). The species which is predominant in the littoral regions of the Great Lakes, and referred to in this paper, is believed to be *Cladophora fracta* (Dillw.).

Growth of the thallus takes place from a perennial rhizoidal holdfast. The algae first appears in the early part of May as a fringe at the waterline. During May and June a rapid growth and spread of the algae occurs and by early July all the suitable habitat is covered with filaments up to 15 in. in length. At this time the filaments are less firmly attached to the bottom and are readily broken by wave action. If strong onshore winds occur when the algae is in this condition, large quantities will be deposited on the shore. The initial period of growth appears to be the most favourable one. After the removal of the first crop, further growth generally takes place, but the quantity produced is usually less. Observations have indicated that variations in the pattern of growth and total production occur from year to year within the same lake. These observations have of necessity been mostly subjective, as no suitable quantitative measurement of production has been devised.

Since at least the early nineteen-thirties, health agencies have received complaints of decomposing, malodorous accumulations along the shoreline in parts of Lake Ontario and Lake Erie (Fig. 1). The black masses of material, emitting an offensive odour, were often mistaken for sewage sludge and many of the early complaints came from persons concerned with the safety of the water for swimming purposes. While there is no health hazard associated with these accumulations, the odours and unsightly conditions seriously affect the aesthetic and recreational value of extended areas of shoreline. Tastes and odours resulting from the decomposition of algae often affect the quality of municipal water supplies, and the frequent clogging of intake screens by drifting algae reduced the capacity of both municipal and industrial water supply facilities.

Municipalities, beach associations and individuals have expressed genuine concern because the underlying reasons for the prolific growths were poorly

a b

Fig. 1. Accumulations of *Cladophora* in Lake Ontario, a) Humber Bay, 1933, b) Oakville area, 1959.

understood and no practical method was available to alleviate the problem. It was also felt that the size and extent of accumulations were increasing each year. In 1959, the Ontario Water Resources Commission undertook an investigation of this problem, and it has continued as a summer project since that time. The study was conducted to determine the reasons for the excessive growths of *Cladophora* and to develop a practical means of control.

DISTRIBUTION OF CLADOPHORA

Several methods can be used to determine the distribution of the areas of growth in the Great Lakes, but each of these has certain disadvantages. Direct observations of the extent of growths can be made by boat, but these are usually limited by turbidity to areas which are less than 6 ft in depth. Aerial surveys can be made and photographs taken, but absolutely calm water and clear weather are necessary. Some success has been demonstrated using this technique in the clearer waters of eastern Lake Ontario, but it has yet to be proven elsewhere. Scuba diving has been used recently for detailed surveys, and while this approach permits accurate observations independent of water turbidity, its use is necessarily limited in surveys over extended areas. Indirect estimation of location and extent of areas of growth can be made by recording accumulations along the shore, and while this is less accurate than direct observation of the algae in situ, it is the most practical on a lake-wide basis.

All of the afore-mentioned techniques have been used to determine the present distribution of *Cladophora* in Canadian waters. To obtain similar information on *Cladophora* in American waters, a questionnaire was sent to the states of New York, Michigan and Ohio requesting information on the known areas of growth in the waters fronting these states. This information is summarized in Fig. 2. No comprehensive surveys appear to have been made in American waters, so that the distribution shown on the map indicates only the areas where growths or nuisances have been reported to occur and is not considered to represent the total distribution. No information is available for that portion of Lake Michigan fronting the states of Illinois and Wisconsin, although some problems have been reported to exist there.

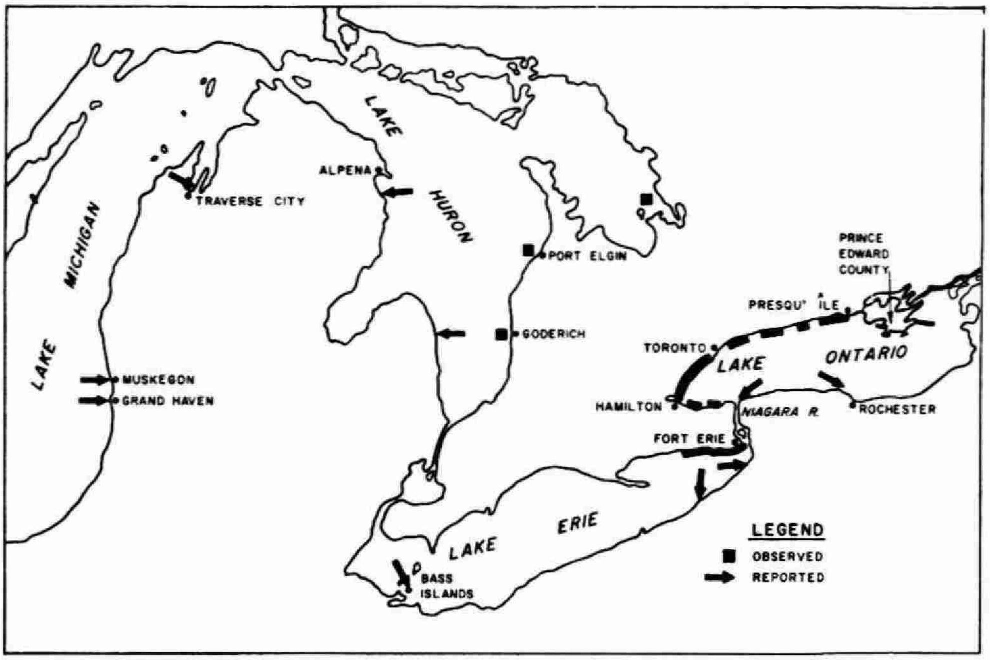

Fig. 2. Distribution of *Cladophora* in the Great Lakes, 1963.

A bottom of bedrock and cobblestones (Ordivician limestone) provides a suitable habitat for Cladophora along most of the shoreline in the Toronto-Hamilton region of Lake Ontario. During the summer, algae accumulates in varying quantities in almost every place where shoreline improvements do not preclude its deposition. While less is known of conditions east of Toronto, a survey of the algal accumulations from Toronto to Presqu'ile Point was made by boat on August 21 and 22, 1963. Accumulations were plotted along a total of 29 miles within this 95 miles of shoreline. Most of these were light, but considerable quantities were noted at Pickering Beach, Whitby, Port Hope and Presqu'ile Point.

During July, the areas of *Cladophora* along the south shore of Prince Edward County and around some of the offshore islands were photographed in an aerial survey conducted by personnel of the Department of Lands and Forests. Growths were found to be associated with points of land and were heaviest along the southwest exposures. Observations were subsequently made by diving to confirm the presence of *Cladophora*. From Prince Edward County east to Prescott on the St. Lawrence River, the growths were not extensive but were prevalent along most of the shore at the waterline. The north shore of Lake Erie, west from the Niagara River to beyond the mouth of the Grand River, is a series of rocky points and sandy bays. Observations made by diving and from the surface indicate that all the rocky substrate of suitable depth supports *Cladophora*. On July 17, 1963, a survey of the quantities and locations of accumulations was made in this area. Deposits up to 50 ft wide and 2 ft deep were noted along a total of 25 miles of this 50 miles of shoreline. In Lake Huron, areas of growth covering 1/2 mile or more of shoreline have been observed at Goderich and Port Elgin. Only one area of growth, surrounding an isolated group of islands, has been observed in Georgian Bay.

ENVIRONMENTAL REQUIREMENTS

Very little has been published on the environmental factors that govern the distribution and abundance of the species of *Cladophora* inhabiting the littoral regions of the Great Lakes. Attempts to grow this species in the laboratory have been unsuccessful, and no laboratory culture experiments have been conducted. The following comments on the physical and chemical requirements and biological relationships have been suggested from field observations made during the course of this study.

Physical Requirements

Water Movement. The importance of water movement has been suggested by several observations. *Cladophora* is most prolific and is established first in niches where a maximum movement of water would be expected. Growth often occurs at the waterline along piers and seawalls in areas which generally do not support a growth on the bottom. It has also been noted that the algae is restricted to fissures and cracks in the bedrock which might be expected to funnel water and provide local turbulence. This is particularly evident in areas considered to be marginal for growth with respect to the fertility of the water. On the other hand, in areas where growths are generally established any enclosure which interferes with the normal movement of water is not populated with *Cladophora*.

Water movement may be the result of both wave action and wind or wave induced currents. Littoral currents, moving parallel to the shore, have been measured at velocities of up to 30 ft per minute and are undoubtedly greater than this at some times. The currents are probably more significant than wave action in governing algal production since they are more continuous and will be effective at greater depths.

The requirement for moving water is believed to be related to the nutrition of the plant. Amberg and Cormack (1960) studied the relationship between the concentration of nutrients and the rate of flow with respect to production of the slime bacterium *Sphaerotilus natans*. Their results show that the amount of nutrients required for a given quantity of growth varies inversely as the flow. It may be postulated that, in a similar way, the production of *Cladophora* will be greater under particularly favourable conditions of flow, even though the fertility of the water may be relatively low.

Substrate. Cladophora requires a firm, stable substrate for attachment. Growth occurs most abundantly on coarse gravel, boulders and bedrock along exposed shorelines where constant wave action prevents the accumulation of sediments. However, significant quantities have also been observed growing on wood, iron, fiberglass, concrete and painted surfaces.

Water Temperature. Cladophora has been found to grow within a wide range of temperatures. In the Toronto-Hamilton area of Lake Ontario, water temperatures during the summer seldom exceed 70°F and may fluctuate as much as 20° within a few hours when wind conditions cause an upwelling of profundal waters. In Lake Erie, however, water temperatures generally increase steadily from spring into summer and wide fluctuations do not normally occur. The most rapid growth of *Cladophora* takes place during the month of June before the water temperature reaches 70°F. After this time, the algae often becomes chlorotic in the distal portions of the filaments and growth in some areas may be terminated. It is not known whether this condition is a direct result of water temperature or whether the availability of essential nutrients also becomes limiting at this time.

Light. From observations, it would appear that there is generally a well-defined depth beyond which the intensity of illumination is insufficient to support growth. In Lake Erie, significant growths do not occur below 13 ft and the production is decreased considerably below 8 ft. In the Toronto-Hamilton region of Lake Ontario, where the waters are less turbid, *Cladophora* grows to a depth of 25 ft and is considerably reduced in depths greater than 12 ft. In the relatively clear waters along the south shore of Prince Edward County, *Cladophora* was found growing to depths of 45 ft. It may be concluded therefore that, where there is a shallow profile, the ability of light to penetrate water can be of considerable importance in determining the area suitable for growth and hence the quantity of algae produced.

Biological Relationships

Cladophora occupies an environment in which no competition exists with higher aquatic plants, as the wave-washed shoreline prevents the accumulation of sediments necessary for their support. However, competition for nutritive elements undoubtedly exists between *Cladophora* and planktonic algae. Epiphytes, predominantly diatoms, are often numerous on the filaments. Cells which are entirely covered are usually dead.

No animal forms are known to utilize *Cladophora* directly for food. Scuds (*Gammarus* spp.) are found on the growths in large numbers, particularly in the latter part of the summer, but whether they are feeding on the epiphytes or on the *Cladophora* has not been determined. Fish native to the various waters are seen regularly in the beds, and young fish utilize the algae for cover.

Chemical Requirements

Cladophora is generally restricted to hard waters and is reported to be indicative of high pH (Prescott 1951). The pH of the Great Lakes water generally lies within the range suitable for optimum growth of *Cladophora* and is sufficiently constant to exert very little influence on growth. Similarly, the physical environment is relatively static and thus affects production only in establishing the potential area suitable for growth. The present distribution of *Cladophora* in the Great Lakes and the total yield within a season in any one area appears to be a direct reflection of the levels of the essential nutrients present in the water. The accelerated eutrophication, particularly of the lower lakes, from artificial enrichment supplied by municipal and industrial effluents and by leaching from and erosion of agricultural soils has substantially increased the mean level of fertility.

In Lake Ontario, numerous sewer outfalls from the urbanized Toronto-Hamilton area, together with influent streams draining fertile lands, are believed to be the sources of nutrients promoting the excessive growths that are continuous along this shoreline. Farther east, along the north shore, isolated areas of *Cladophora* are usually associated with municipal outfalls and tributary streams that often occur together. However, along the south shore of Prince Edward County, significant quantities of *Cladophora* are established without any apparent local source of added enrichment. In this area, the physical aspects of the environment are particularly favourable for growth and it would seem that, under these conditions, the basic level of fertility of Lake Ontario is sufficient to support marginal growths.

Along the Canadian shores of Lake Erie, *Cladophora* has been observed to grow over most of the suitable rocky bottom. At Crystal Beach a sewer outfall provides a local source of enrichment resulting in a considerable

increase in the quantity of algae produced. Several other isolated growths of *Cladophora* are present in Canadian waters. Two in Lake Huron are associated with the presence of sewer outfalls. One area of growth has been observed on a remote island in Georgian Bay. This is an island extensively used by gulls for nesting purposes, and apparently sufficient nutrients are carried to the water to promote the growth of *Cladophora*. Lake Huron and Lake Superior appear to lack the basic fertility necessary for even marginal growths.

DETERMINATION OF THE LIMITING FACTOR

Where physical conditions are suitable, growth may be limited by the nutrient that is present in the least quantity with respect to the needs of the algae. Because of the relatively low concentrations of available nitrogen and phosphorus in the lake water under natural conditions, it was believed that the excessive growths developing in artificially enriched waters were primarily the result of increased concentrations of one or both of these elements. Attempts were made to determine which of these was the key factor and to determine the concentration below which growth did not take place.

Previous to 1963 a large number of water samples had been analyzed for nitrogen and phosphorus. Comparisons were attempted using the results of samples which were taken from areas supporting growth and from those which did not. However, no corre ation was detected. The failure of this approach was believed not to be because differences did not occur, but because it was difficult to accurately measure small changes in the relatively low concentrations of these elements. There is also the probability that these nutrients are taken up in excess during the more favourable periods. To detect this condition, a continuous monitoring program would be required.

As the analytical approach had not identified the limiting factor, an alternative experiment was carried out during 1963. Essentially, the plan was to feed nitrogen and phosphorus separately and combined, as well as an organic fertilizer, to an environment which provided a suitable physical habitat but which was entirely devoid of *Cladophora*. The site selected was at Douglas Point, Lake Huron (Lat. 44° 20' N, Long. 81° 36' W). This area provided approximately 5 miles of exposed, irregular shoreline having a bedrock and cobblestone bottom. Fig. 3 shows the location of the 4 sites selected. The substance and quantity applied at each site are shown in Table 1. The experiment commenced on June 24 and continued until September 25. To ensure the availability of "seed" material, rocks having a growth of *Cladophora* were moved to the area and ten of these were placed in approximately 3 ft of water at each site and at a fifth

Table 1. Nutrients and Rates Used in Artificial Enrichment Experiments at Douglas Point

Site	Nutrient	Product	Total (lbs)	Avg./day (lbs)
1	Nitrogen As N	Ammonium Nitrate (33%)	495	5.6
2	Phosphorus As P_2O_5	Triple Super Phosphate (46%)	538	6.0
3	Organic Fertilizer	Sheep Manure	1,107	12.0
4	Nitrogen (N)	Ammonium	468	5.2
	Phosphorus (P_2O_5)	Nitrate (33%)	257	2.9
	Potassium (K_2O)	10-52-17	88	0.9

location to provide a control. The addition of somewhat greater quantities of chemicals than those indicated in Table 1 was planned initially, but because of difficulties with the feeding apparatus during the early part of the experiment, something less than the expected quantity was actually applied.

The chemical characteristics of the water in the vicinity of the control area were determined, and the results are presented in Table 2. Observations were made regularly to watch for any changes that might occur within the fertilized areas. On July 19 a small growth of *Cladophora* was first observed at Site 3, in response to the application of sheep manure. A small quantity of effluent from an oxidation pond also entered the lake at this site. By August 8, a bed of *Cladophora* covering an area of about 200 sq ft had developed at Site 2 where phosphorus alone was being fed. In the latter part of August, *Cladophora* became established at Site 4, where a combination of phosphorus, nitrogen and potassium was being fed. Throughout the period of the experiment, no new growth developed from the nitrogen enrichment at Site 1, although the algae on the "seed" rocks persisted. There was no spread of growth in the control area and the "seed" rocks were devoid of algae by the end of August. The ultimate extent and pattern of growth which became established are illustrated in Fig. 4.

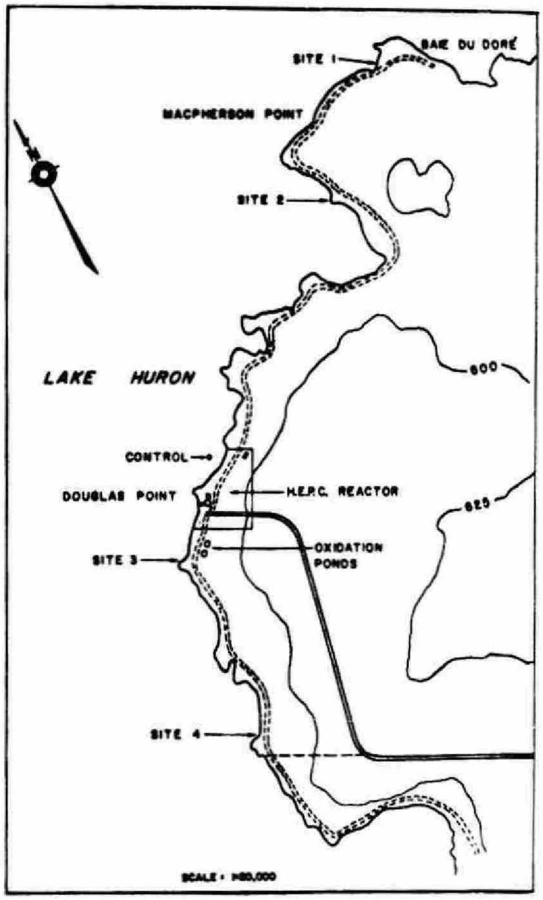

Fig. 3. Sites selected for enrichment experiments at Douglas Point.

The results of these experiments indicate that phosphorus was the nutrient responsible for the growth of *Cladophora* at Douglas Point. Further, it

Table 2. Water Quality, Douglas Point, June-September 1963 (results from 12 samples)

	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Specific conductance (25°C)	pH	Phosphorus Total	Phosphorus Sol.	Dissolved solids	Turbidity (SiO_2 units)
Min.	92	80	150	7.0	0.01	0.00	120	0.2
Max.	106	88	180	8.4	0.06	0.03	162	1.5
Avg.	97.3	84.2	169.0	8.04	0.024	0.013	137	0.73

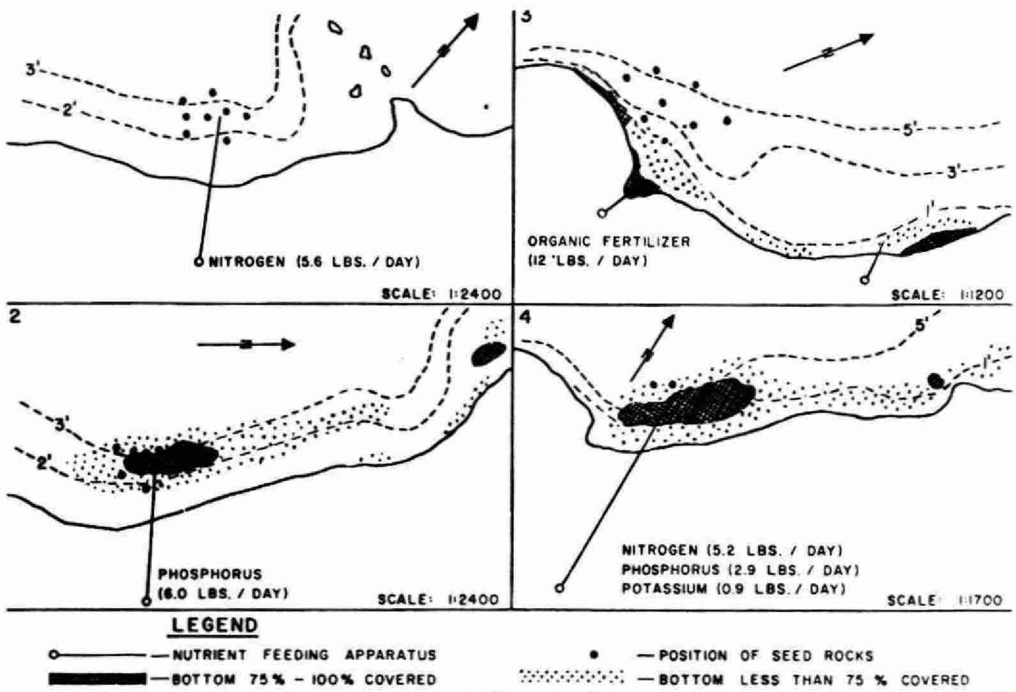

Fig. 4. Pattern of *Cladophora* development in response to artificial fertilization at Douglas Point.

would appear that the growth of *Cladophora* is limited in other ecologically suitable habitats because of insufficient concentrations of phosphorus. The level of phosphorus in Lake Ontario and Lake Erie is apparently sufficient to sustain growth and any additional phosphorus applied to these lakes will be reflected by a more prolific growth of *Cladophora* and an intensification of the problems it causes. A much more sophisticated study would be required to determine the minimum concentration of phosphorus necessary to sustain growth. However, these experiments did indicate that at a feed rate of 2.9 lb per day a bed in excess of 10,000 sq ft was established where *Cladophora* did not previously grow and in a season of the year less than optimum for growth.

CONTROL STUDIES

The apparent methods for controlling this problem are 1) by effecting an environmental control through a reduction of the basic nutrients in sewage effluents, or through a modification of the physical environment, 2) by controlling growth through the use of algicides, or 3) by mechanically removing the algae from the areas of growth or from the areas where it accumulates.

1. The control of *Cladophora* through the limitation of nutrients is technically a difficult problem since the conventional methods of treatment are not designed to remove the basic nutrients. Considerable research on a world-wide basis is presently being undertaken to develop a practical means for the removal of fertilizing elements from sewage effluents. It is felt that the elimination of phosphorus from this source would limit the growth of *Cladophora* in most areas.

2. Studies have been made both in the laboratory and on an experimental scale in the lake to determine the algicide most suitable for controlling *Cladophora*. A procedure for the screening of potentially useful algicidal substances was developed, and to date 21 of these have been evaluated. The best results have been achieved using the chemical Hydrothol at a concentration of 1 ppm active. However, the cost of this material would appear to limit its usefulness over extensive areas of shoreline. Variations in the effectiveness of this and other chemicals due to variations in temperature, water movement, and other factors have been noted.

3. A study has been made of the possible equipment which might be useful in disposing of algae which has accumulated on shore. The rugged nature of the shoreline in many areas precludes the use of most conventional equipment. Hydraulic procedures were the most effective in preliminary tests and further developmental studies are planned.

SUMMARY

Cladophora in some specific areas of the Great Lakes constitutes a serious nuisance problem. There is evidence that the areas of growth are becoming more extensive and that the production on existing beds is increasing. Evidence has been presented in this paper that nuisance conditions are related to eutrophication and that phosphorus is probably the key element involved. Eutrophication of Great Lakes waters is reported to be taking place, and should it continue it may be expected that the problems created by *Cladophora* will become more widely distributed and more serious in both Canadian and American waters.

The work of the Commission in embarking on these studies has of necessity been very broad, as virtually no previous studies have been made. It is intended that research in this field will continue. In the immediate future an attempt will be made to devise a means of measuring the production of *Cladophora* quantitatively to obtain further information on the effect of fertility levels, light, temperature, season and other environmental factors, and also to permit the measurement of annual variations, differences between specific locations, and changes over an extended period of time.

Looking towards a short-term solution to the problem, laboratory screening of an extensive group of chemicals is planned, and preliminary field tests will be made on any that appear promising. Further extensive testing is contemplated for two chemicals that have been found to be effective in preliminary lake trials. A survey will be undertaken to determine the relative amounts of fertilizing elements, particularly phosphorus, that are contributed by municipalities, industries and land drainage, to the Canadian waters of the Great Lakes.

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STATUS REPORT

ON

CLADOPHORA

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and

G. E. Owen

September 30, 1965

STATUS REPORT ON CLADOPHORA

INTRODUCTION

Branched filamentous green algae of the genus *Cladophora* have increased notably in Lake Ontario and Lake Erie, a condition which is considered to reflect the accelerated enrichment of these two lakes. After a period of rapid development in early summer, the algae characteristically becomes detached from the rocky areas where it grows and is carried ashore during periods of stormy weather, often near the end of July. The algae decomposes in shallow water under the hot sun, producing a black, aesthetically undesirable accumulation that produces a foul "pigpen" odour. This odour is particularly objectionable when the wind is onshore. Besides reducing property values and interfering with the recreational utilization of beach areas, *Clado hora* has clogged water intakes and has seriously affected commercial fishing operations by accumulating on gill nets, almost totally reducing their effectiveness.

NATURE OF INVESTIGATIVE WORK

As a result of numerous complaints of widespread nuisances caused by shore accumulations of *Cladophora* during the summers of 1957 and 1958, the Ontario Water Resources Commission sponsored a

conference in November of 1958 to discuss the apparent causes and effects of the excessive growths in Lake Ontario and Lake Erie and to decide what action should be taken. Since that time, investigations have been carried out each summer to obtain fundamental information on the life history of the alga, the magnitude and distribution of growths in the Great Lakes, and the physical, chemical and biological environmental factors affecting growth. From an understanding of these environmental factors, it was hoped that one or more critical factors could be altered in such a way as to bring about less favourable growth conditions and thus effect, indirectly, some degree of permanent control. At the same time, it was recognized that an understanding of the complex interactions of various factors combining to cause excessive growth would require a long-term study and because of the difficulty in effecting changes in large bodies of water, permanent control measures would require a number of years to implement. Consequently, a major part of the study was devoted to an evaluation of chemical means for controlling growths more as an immediate rather than permanent solution in relieving nuisance problems. All available algicidal chemicals,as well as a number of other chemicals suspected of having potential algicidal properties, were tested in lake trials to determine their suitability for controlling Cladophora growths. Consideration was given to the relative toxicity of these chemicals at

various concentrations, methods of application, cost, and effect on fish and other beneficial organisms at concentrations required to kill Cladophora. More recently, a laboratory procedure was established for rapid screening of a wide range of chemicals.

Also, as a temporary means of alleviating nuisance problems, preliminary studies were carried out to evaluate various mechanical means of removing algae that accumulates on shore. These involved an assessment of mechanical methods being used by a number of municipalities and property owners' associations, the development and testing of new equipment that could be used where difficult shoreline conditions exist, and a survey of equipment being produced commercially for beach cleaning and its adaptability to the problem.

Some preliminary studies, involving analyses to determine the chemical composition of Cladophora, were also carried out to explore the possible use of the algae as a feed supplement or fertilizer.

ENVIRONMENTAL FACTORS AFFECTING PRODUCTION OF CLADOPHORA

Important physical factors affecting production of Cladophora are light, temperature, wave and current action and type of substratum. Also the availability of important plant nutrients is of key importance in determining the distribution and production of the algae.

Cladophora grows along exposed shorelines in Lake Ontario and Lake Erie wherever a firm, stable substratum is present. The extent of rocky bottom, therefore, determines the potential areas of production. While any type of rocky bottom is suitable, the greatest production results where a cobblestone bottom is present. The influence of light on the production of *Cladophora* is affected by patterns of sunshine and cloud cover, water depth and turbidity, the latter in turn influenced by meteorological conditions and phytoplankton production.

It is known that nitrogen and phosphorous are two key nutrients insofar as plant production is concerned, and it is certain that increased contributions of these in sewage plant and industrial discharges is causing excessive development of *Cladophora*. Analytical work revealed greater concentrations of these chemicals near shore in Lake Ontario. However, concentrations of these nutrients that will support *Cladophora* are so low that existing analytical procedures do not permit correlations to be established between nutrient concentrations and varying production patterns along the lake.

Fertilization experiments were conducted along remote rocky shoreline areas of Lake Huron, devoid of algae growths, to determine the relative importance of nitrogen, phosphorous and an organic fertilizer in promoting the development of *Cladophora*.

Phosphorous was fed continuously for a three-month period at one study area, nitrogen at another, a combination of the two at a third, and inorganic fertilizer was applied at a fourth location. Cladophora developed in the two areas where phosphorous was fed and to a limited extent where organic fertilizer was added. No Cladophora developed where only nitrogen was applied. This experiment indicated therefore, that phosphorous is a more significant limiting factor than nitrogen. It is felt that reducing the input of phosphates to the lakes affords the most practical means by which lasting environmental control can be effected. Analyses have been completed which indicate the relative contributions of phosphorous from municipal and agricultural sources in the Toronto area but this information has not yet been evaluated. Quantities of phosphorous delivered to the lakes through effluent streams are now being monitored by the Water Quality Surveys Branch.

Marked variations in the production of Cladophora have been noted. To develop an understanding of these fluctuations is difficult because of the complex interaction of physical and chemical factors in determining ultimate production. Laboratory culture of Cladophora under controlled conditions, along with continuing field studies, are required to clarify the relative importance of these interdependent variables.

OBSERVATIONS ON THE DISTRIBUTION AND GROWTH OF CLADOPHORA AND SHORE ACCUMULATIONS

The growth of Cladophora usually begins during the middle of May in Lake Ontario and Lake Erie and continues at a rapid rate during May and June. By early July, dense stands of algal filaments cover extensive areas of rocky bottom to a depth of 13 feet in Lake Erie and to a depth of more than 20 feet in Lake Ontario. During strong onshore winds, most of the algae growing in depths of less than 10 feet becomes detached and is washed ashore.

From aerial photographic surveys, it has been estimated that growth beds within the 10-foot contour along the Lake Ontario shoreline between Toronto and Burlington cover a total area of 2,292 acres. From similar photographs taken of the Lake Erie shoreline between Ft. Erie and Pt. Maitland it has been estimated that the area of Cladophora growths, subject to removal by wave action, is in excess of 5,000 acres. These figures indicate the extent of growths along only a small portion of the total shoreline. In Lake Ontario growths of nuisance proportions extend from Prince Edward County to Burlington and along the south shore at least as far as St. Catharines.

Nearly one third of the 95 miles of shoreline between Toronto and Presqu'ile Point is affected by significant accumulations of algae with heaviest accumulations occurring at

Presqu'ile Point, Cobourg, Port Hope, Oshawa, and Frenchman's Bay. Accumulations affect nearly the entire shoreline from Toronto to Burlington and from Van Wagner's beach in Hamilton to Jordan Harbour. From surveys made along the fifty miles of shoreline between Ft. Erie and Pt. Maitland, it was estimated that 25 miles were affected by algal accumulations. Nearly all of these accumulations were in sandy bays, in areas heavily utilized by tourists and private cottage owners. In Lake Huron excessive growths of *Cladophora* have not as yet developed over extensive areas. However, local growths of *Cladophora* have appeared at Goderich, Pt. Elgin, and Southampton and in the Thornbury-Meaford vicinity of Georgian Bay, apparently in response to increased enrichment of the water at these points. At Goderich, nuisances have recently developed along both public and private beaches.

EXPERIMENTAL CONTROL MEASURES

Chemical: Since 1957 thirteen chemicals have been field tested against *Cladophora*. Altogether 62 individual field tests have been completed on plots ranging in size from one acre to fifteen acres. Both liquid and granular algicides have been tested and applications have been undertaken both by boat and by aircraft. Screening trials have been completed in the laboratory for 67 different chemicals, most of these being tested at three

different concentrations and for two different exposure periods (one and four hours). All this work has pointed to the fact that Hydrothol is the most satisfactory chemical control agent. For large-scale applications, granular Hydrothol should be applied by aircraft at a rate of 1 ppm of the active ingredient. Application by boat, while satisfactory from the control standpoint, is not feasible except for small experimental plots. Hydrothol costs $65.00 an acre and including application charges, the total cost of treatment is approximately $100.00 an acre. Although Hydrothol is toxic to fish at sub-application concentrations in laboratory tests, no significant mortalities of fish have developed during actual field trials. It would not be desirable to use the chemical in the vicinity of municipal water intakes because the chemical would produce a detectable taste at the concentration employed and because label directions indicate that treated water should not be used for human consumption.

MECHANICAL MEANS OF REMOVING ALGAL ACCUMULATIONS

From a survey of equipment which has been developed commercially for the removal of debris from beaches, it was concluded that this type of equipment is generally unsuitable for handling *Cladophora*. These machines are not designed for

operating in the water nor to handle the type and volume of material usually involved.

Observations were made in a number of areas on the types of equipment being used for algae removal. These methods include the use of bulldozers, front-end loaders, mechanical rakes and hand-raking. The equipment used most widely and which appeared most efficient was the York rake mounted on the rear of a tractor. This equipment, however, is restricted to use on smooth gravel shores or sand beaches. It was felt that studies should be conducted to develop a more versatile and efficient system which would be adaptable to all types of shore where algae accumulates. Tests were conducted during the summers of 1963 and 1964 at Silver Bay on Lake Erie, and Presqu'ile Point. Two principle systems were evaluated: Rotary brushes operated by a tractor for picking up or piling the algae on the shore and high-capacity centrifugal pumps for the removal of accumulated algae from shallow water areas. In general the results of these tests showed that the rotary brush system was entirely ineffective. The most efficient system tested was the use of a York rake to move the algae from shallow water to the intake of a 6-inch centrifugal pump. The algae was pumped on to shore for disposal. Using this system, it was demonstrated that 50 cubic yards of algae lying along 100 feet of sand and rock shore could be removed in six hours at a cost of three dollars per cubic yard. This removal was 90 per cent effective.

UTILIZATION OF CLADOPHORA

From analyses of thirty samples, it was concluded that *Cladophora* is equivalent to low grade sun cured alfalfa meal. A number of processing problems, such as removal of sand, would require solution. Experimental animal feeding and palatability studies would be necessary to determine its value as a feed stock.

Cladophora is equivalent to peat moss as a soil conditioner and is a low grade fertilizer.

1967 CLADOPHORA INSPECTIONS

Inspections were made of the Lake Erie and Lake Ontario shorelines during the last two weeks of August. Inspections were made by boat and by car and where possible observations were supported by enquiries from residences and parks personnel.

CONCLUSIONS

It would appear that Cladophora growth and accumulations created fewer problems this year than in the past four or five years, with a few exceptions. Cedar Bay on Lake Erie and Port Darlington, Bowmanville, are two locations which had offensive and heavy accumulations which caused people to submit complaints to the OWRC.

On Lake Erie the frequency of algae accumulations on shore increased from west to east toward the mouth of the Niagara River, so that there was almost a continuous band from Crystal Beach east. However, even this band was considered to be light.

On Lake Ontario, the odourous accumulations were located in the area from Burlington Bay to Jordan Harbour but there were many clear areas in between. East

from Toronto, there were only two areas in which algae created a problem this summer - Port Darlington had a very heavy accumulation in late August and park personnel at Cobourg hauled away an accumulation in mid-July.

In general the much higher water created a beneficial effect in lessening the problems caused by odourous Cladophora accumulations during 1967. Much less fore-shore was exposed and gentle wave action removed many of the algae accumulations that were originally on the beaches. Also, the fact that there were fewer prolonged violent winds this summer probably accounted for the lack of large accumulations on shore, particularly in Lake Ontario.

LAKE ERIE - August 17, 1967

1.	Dunnville	S. Platts Bay	- odourous, 3' - 4' deep on shore
2.	Rock House Pt.	L&F Park	Algae worse than last year, growing more, accum. on pt. None on beach (swimming). Removed 20 - ½-ton truck loads during season.
		Pt. Maitland Fishermen report large mass in lake well offshore. Luxuriant growth about 12-16" in length as a fringe on east shore of Rock House Pt.	

3.	Mohawk Point ½-way down east side.	Heavy black accumulation 10' wide for 1000' - in and out of water. Rest of shore has light fringe 2' wide.
4.	East of Lowbanks	Small pocket creating odour.
5.	Long Beach Park	Beach clean through efforts of park maintenance crew. One week of wind at end of July blew in a lot.
6.	Grabells Point	Bay on east has 20-foot wide black soupy belt, 800' long, 1' deep.
7.	East side of Morgan's Point	Small pocket at west end of Gravel Bay - black and soupy.
8.	"	Some dry algae high on shore on east side of Morgan's Point.
9.	Rathfon Point	Healthy green growth on vertical side of rocks.
10.	Reebs Bay	Black accumulation in pocket of Bay.
11.	Sugar Loaf Point	Odourous accumulation across length of Bay in a narrow band.
12.	Between Cassaday Point and Pine Crest Point	Light accumulation of green Cladophora on beach 4' fringe.
13.	Dr. Lemon - Cedar Bay	Cedar Bay clean-up operation: 1961 - First raking June 26 1962 - : " " July 10 1963 - " " " 15 1964 " " 22 1965 " " Aug. 6 1966 " " July 11

1967 - First	raking	July	3
2nd	"	"	4
3rd	"	"	5
4th	"	"	20
5th	"	"	26
6th	"	"	31

Heavy accumulations directly in front of Dr. Lemon's place.

Much narrower foreshore. No place to pile accumulated algae.

AUGUST 18, 1967

14. Silver Bay	Saw Herb Chambers who was hauling away accumulations. Silver Bay Beach (west end) had a black soupy accumulation 5' - 10' wide. Mr. Chambers claims that there is only about 30% as much this year in comparison to last according to loads he has hauled away.
15. Shisler Point	Sherkston Park - Beach clean but have hauled away a large amount earlier this year.
16. Point Abino	East side - from Buffalo Yacht Club - out around tip of point past lighthouse to the west. Several heavy pockets of accumulations - very odourous.
17. Crystal Beach - west of pier	heavy deposit of black soupy decomposed algae.
18. Windmill Point - west	Heavy accumulation in small pocket at end of sand beach.

19.	Bertie Twp. W.T. Plant	No algae has blocked their screens this year. Less accumulated on shore.
20.	Fort Erie	Some green and some dry algae on breakwall near Water Pumping Station. Accumulation west of Fort property.

AUGUST 15, 1967

LAKE ONTARIO

1. Extensive growth covering 100% of bottom - 8" to 12" long between Oakvile to Port Credit Hydro Plant.

2. From Hydro Plant east to Humber, there was less 'growth'. Very little of this was on shore. A small amount of algae was high and dry on the shore and had been there for some time.

3. East of the Humber River behind the breakwall - there were rooted aquatics with plumes of Cladophora interwoven in dense growths.

AUGUST 16, 1967

4. Oakville to Hamilton Beaches. Heavy growths of Cladophora 10 - 15" long. Few accumulations on the shore. Some dry Cladophora on shore.

5. Coronation Park - Bronte - some loose algae in the shallow water 100% growth on the point but not too long, 4 to 6 inches.

6. The only large shore accumulation was at a swimming beach just north of the Burlington Bay canal on the lake side. It was the first amount blown in this year according to lifeguards.

7. From Burlington Canal south and east, there were small accumulations in the lee of rock piles which act as breakwalls.

8. Between Stoney Creek and Jordan Harbour, there were small heavy pockets of algae which were odourous - usually caught on docks and rock projections.

9. Grimsby Water Treatment Plant. A small pocket against pier was quite odourous but the operator said that they have not had too much piled on shore this year, and, that which has come in has been quickly washed back out due to high water.

AUGUST 30, 1967

CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY, 14 Frank St., Bowmanville, Ontario - Tel. 623 3788

10. No algae at base of Scarborough Bluffs.

11. Marina operator who has been making observations for 10 years near Highland Creek S.T.P. stated that due to high water (about 2' higher) that no algae has come in yet.

12. There was a very light fringe of dried algae at the end of Port Union Road.

13. Rosebank Station clean.

14. Fairport Beach clean.

15. Frenchman's Bay beach - clean.

16. Squires Beach - ok.

17. Point at foot of Harewood Avenue, Ajax - west of Filtration Plant, first noted heavy accumulation, fresh and green.

18. Pickering Beach Road - no algae.

19. Whitby Harbour - west - very little algae - light fringe on rocks.

20. Whitby Harbour - east - no algae - some dry material high on beach.

21. Oshawa Pumping Station - no algae.

22. Darlington Provincial Park - very light fringe of algae - small pocket of soupy algae at east end of swimming beach. Superintendent thinks there is the same amount or less algae than last year.

23. Port Darlington, Bowmanville - heavy accumulation in Harbour mouth - none on shore, east of harbour 20' wide - 200' long.

24. Bondhead, Newcastle - small pocket of accumulation - 10' wide, 500' long

25. Newtonville - Port Grandby - no algae.

26. Port Britain - small accumulation on rocks.

27. Port Hope - small strip at east end of swimming area, west of harbour.

28. Cobourg - west - light wide fringe along entire shore.

29. " beach - Parks Department - removed a heavy quantity early in July - less than in other years - beach clean since then.

30. Chub Point, Grafton - several very light fringes strung along beach.

31. Colborne - lake front - a light fringe of green along shore 2' wide.

32. Presqu'ile - west beach - heavy fringe 10' wide, 2" deep along entire beach.

33. Very heavy accumulation on shore area between island channel and south shore.

34. According to park attendants, they have been able to keep ahead of any accumulations this year. Only small quantities have come in. They also claim there is far less blown up onto the island's beachethis year in comparison to last year when the entire island shoreline was caked with a heavy brown mat of dried algae.

35. Bowmanville - Stopped in at Central Ontario Conservation Authority. Sample submitted by them came from west beach at Port Darlington where 3 weeks ago a continuous heavy fringe was on shore.

EVALUATION

A <u>light fringe</u> is defined as any amount which shows a green coloured broken or continuous line along the shore, up to a band which may be a foot wide but less than one inch deep.

<u>Light accumulations</u> may be anything from 1" deep to 3" deep and up to 5' wide but not odourous.

<u>Heavy accumulations</u> are bands of algae over 6" deep and greater than 5' in width usually creating an odour.

<u>Algae</u> - The word algae and Cladophora are synonymous in these notes.

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